

Horizon scanning to identify invasion risk of ornamental plants marketed in Spain

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Abstract

Horticulture is one of the main pathways of deliberate introduction of non-native plants, some of which might become invasive. Of the 914 commercial ornamental outdoor plant species sold in Spain, 700 (77%) are non-native (archaeophytes excluded) marketed species. We classified these into six different lists based on their invasion status in Spain and elsewhere, their climatic suitability in Spain and their potential environmental and socioeconomic impacts. We found sufficient information for 270 species. We provide a Priority List of eight regulated invasive species that were still available on the market. We also established an Attention List with 68 non-regulated invasive and potentially invasive species that might cause various impacts. To prioritise the species within the Attention List, we further assessed the risk of invasion of these species by using an adaptation of the Australian WRA protocol and the level of societal interest estimated from values of the Google Trends tool. We also propose a Green List of seven species with probably no potential to become invasive, a Watch List with 27 potentially invasive species with few potential impacts and an Uncertainty List with 161 species of known status but with insufficient information to include them in any of the previous lists. We did not find sufficient information for 430 (61%) of the marketed non-native plant species, which were compiled into a Data Deficient List. Our findings of prohibited species for sale highlight the need for stronger enforcement of the regulations on invasive plant species in Spain. In addition, our results highlight the need for additional information on potential impacts and climate suitability of horticultural plants being sold in Spain, as insufficient information could be found to assess the invasion risk for most species.

Keywords

e-commerce, Google trends, horizon-scanning, impact assessment, non-native plants, nursery, priority list, risk assessment

Introduction

The introduction of invasive non-native species by humans may be accidental – for example seed crops as contaminants amongst cargo – or deliberate (Mack et al. 2000), such as the introduction of species used in forestry, aquaculture and horticulture. In particular, the sale of ornamental plants, including sale by nurseries, is the main deliberate pathway for plant invasions (Van Kleunen et al. 2018) which includes some of the most harmful invasive plant species in the wild (Hulme 2007).

There is a close relationship between domestic market-based propagule pressure and invasion success (Dehnen-Schmutz et al. 2007a; Johnston et al. 2009; Blackburn et al. 2013; García-Díaz et al. 2015). Horticulture activities reduce biotic and abiotic stresses on plants, bring species of different geographic origin together and increase the likelihood that plants escape into the wild (Niinemets and Peñuelas 2008). Moreover, introduction biases, or preferences for non-native species that perform better than natives (Chrobock et al. 2011), include plants that have increased germination rates, faster and larger growth and higher fecundity than native plants (Chrobock et al. 2011; Parker et al. 2013; Maurel et al. 2016). Therefore, the commercial use of non-native ornamental plant species is not only important as the main pathway of introduction (Hulme 2007), but it also favours the invasion potential of these plants and their impacts. In fact, in less than 20 years on the market, some non-native species can become invasive (Pemberton and Liu 2009).

The most effective way to manage the impacts of non-native species is through prevention (Convention on Biological Diversity 2010). In the last two decades, there has been great progress in developing risk assessment protocols as an essential management component to identify potentially invasive species (Pheloung et al. 1999; Leung et al. 2012; Roy et al. 2014, 2015). Most of these risk assessments are used to rank non-native species according to their probability of becoming established and causing harm. Horizon-scanning of invasive species is a particular type of rapid screening risk analysis based on the systematic examination of future potential threats, leading to the prioritisation of non-native species for further investigation (Roy et al. 2014). Horizon-scanning has been applied when prioritisation identifies a small fraction of species selected from a large list of scanned species, for which a thorough risk analysis is not feasible in a short period of time (Andreu and Vilà 2010; Roy et al. 2015; Roy et al. 2019). This is the case, for example, for testing the invasion risk of all ornamental plants commercialised within a country because the number of non-native plant taxa sold is very high.

A parsimonious way to perform a horizon-scanning analysis for ornamental plants is to use four of the most widely used criteria to identify potentially invasive species: climate matching, being invasive elsewhere, their potential impacts on the environment and their impacts on socioeconomic activities (Weber and Gut 2004; Otfinowski et al. 2007, Gassó et al. 2010; Blackburn et al. 2014; Roy et al. 2014).

As the number of non-native species being used as ornamentals is very high, but resources are limited to manage them all in the same way, it is necessary to create prioritisation lists of plant species identifying those that are (1) regulated invasive but still

commercialised, (2) potentially invasive with the risk of causing numerous impacts, (3) potentially invasive with few potential impacts, (4) probably safe because there is no potential to establish in the wild and (5) those for which there is insufficient information to classify them by their risk of invasion and impact (Dehnen-Schmutz 2011). This coarse screening is the basis for prioritising the potentially most invasive species and to later perform a more detailed risk assessment (Pheloung et al. 1999; Weber and Gut 2004; Andreu and Vilà 2010; Gassó et al. 2010), as well as for proposing a list of the least harmful species (Gedera et al. 2012).

Since many regulations expressly prohibit the commercialisation of listed species, it is expected that none of them is sold. However, regulation is not always effective, especially for the online plant trade (Humair et al. 2015). In fact, many nurseries continue to stock and supply invasive regulated species (Wirth et al. 2004; Cronin et al. 2017). In addition, nowadays most of the nurseries offer internet purchasing. This model of commerce is currently one of the most important sources of gardening plants (Humair et al. 2015). The online plant trade significantly increases transportation distance and propagule pressure of non-native species (Walters et al. 2006; Lenda et al. 2014; Humair et al. 2015). As an innovative approach, the Google Trends tool can be used to forecast consumption and commerce, which is a valuable source of information (Vosen and Schmidt 2011). Therefore, the level of interest in each ornamental species measured by Google Trends can provide information on the interest for a particular species by society in general. Google Trends provides information on how frequently a keyword or group of keywords has been searched for on the Internet. Resulting data are not necessarily composed of only people interested in buying the plant. In fact, it is possible that some of these searches are performed because they are looking for ways to control or manage already invasive species. In our study, we used Google Trends data to assess “popularity” or “interest”, defined in a broad sense, as the data do not allow distinguishing whether plant name searches were motivated by Internet users’ positive or negative views of a plant.

To our knowledge, this tool has not yet been used for the prevention of biological invasions.

In this paper, we perform a horizon-scanning analysis of the 914 commercial ornamental outdoor plant species in Spain from a total of 1063 taxa to facilitate policy implementation. The main aim is to generate six species lists based on their regulation and invasive status in Spain and elsewhere, climate matching between their native region and Spain, the magnitude of the environmental and socioeconomic impacts they might cause and their societal interest (Fig. 1):

- A Priority List that includes regulated (by Spain or the EU) invasive non-native species that were still commercially available in the Spanish peninsular territory (Spain, hereafter).
- An Attention List that includes climatically suitable non-regulated invasive in Spain and potentially invasive species (i.e. invasive elsewhere) with many potential impacts.
- A Watch List that includes climatically suitable non-regulated invasive in Spain and potentially invasive species (i.e. invasive elsewhere) with few potential impacts.

- A Green List that includes species with no climatic suitability and probably no potential to be invasive in Spain.
- An Uncertainty List that includes non-invasive species with probably no potential to be invasive that do not meet the requirements to be included in the Green List. It also includes species with known invasion status but with insufficient information available on impacts and non-native species with known invasion status but with insufficient information on climatic suitability or invasiveness elsewhere.
- A Data Deficient List with all the non-native species with no information about their invasion status and not enough data to classify them in any other list.

To rank the species of the Attention List, we conducted an in-depth analysis based on their risk of invasion and societal interest. The risk of invasion was scored according to the Australian weed risk assessment performed by Pheloung et al. (WRA 1999). This WRA protocol has been tested successfully for its consistent accuracy in different geographic regions (Gordon et al. 2008) including Spain (Gassó et al. 2010). Societal interest in non-native species was measured using Google Trends. We wanted to answer the following questions: Does the risk of invasion and interest to society grow across the different invasion status groups of species currently in Spain (i.e. not in the wild, casual, naturalised and invasive)? Does the number of potential environmental and socioeconomic impacts rise with increasing invasion status. Moreover, for each non-native species, we calculated a Priority Index based on the impacts, WRA score and interest of the species. We tested if the Priority Index increased with increasing invasion status of the species.

Material and methods

We compiled a database including the vast majority of ornamental outdoor plants with commercial use in gardening in the Spanish peninsular territory excluding the Canary and Balearic Islands (Spain, hereafter). We also included indoor plants that can survive and/or reproduce outdoors. However, we excluded strictly indoor plants because their ecological requirements might prevent survival outdoors. We included fruit trees as they are of ornamental use in public and private gardens and green areas, but we excluded vegetables used in horticulture. The list of taxa was compiled through the systematic consultation of catalogues from the 21 main Spanish nurseries (Appendix 1) between December 2015 and October 2016, which provide plants for sale across the country. The number of new taxa added to the database (Appendix 1) did not increase at all after the 15th nursery catalogue was consulted. The total number of taxa compiled was 1036, of which 914 were actual species. Hybrids or genus level taxa were not included in the analysis and infraspecific taxa were pooled into species.

According to their origin, we first discriminated between native species and non-native species in Spain. We then identified archaeophytes (i.e. species introduced be-

fore 1500 A.D.), following Pyšek et al. (2004). Archaeophytes were not included in the analysis because they are poorly recorded and, for many species, their non-native status is under discussion.

Species were further classified according to their invasion status in Spain, following the definitions recommended by Richardson et al. (2000): not in the wild, casual, established or naturalised (hereafter “naturalised”), invasive non-regulated in Spain or Europe (hereafter “invasive”) or invasive regulated in Spain or Europe (hereafter “regulated”). Invasion status in Spain, as not in the wild, casual, naturalised or invasive, was based on the information provided in the Spanish Atlas of Invasive Non-native Plants (Sanz Elorza et al. 2004). The regulation status of the species, that in Spain involves the ban of possession, transport and commerce of living beings and propagules, was based on the Spanish Catalogue of Non-native Invasive Species (BOE 2013) and the List of Invasive Alien Species of Union Concern (European Commission 2016, 2017).

Once the non-native species were classified into these five invasion status groups (i.e. regulated invasive, invasive, naturalised, casual, not in the wild), we proceeded to perform the horizon-scanning to classify the species into the respective lists based on the flow diagram illustrated in Fig. 1 as follows:

All Regulated species were directly included in the Priority List, whereas invasive species were considered for impact assessment (see method below).

Naturalised species were identified as invasive elsewhere, based on the CABI Data-sheets (2018) and the Global Invasive Species Database (Invasive Species Specialist Group 2015). Naturalised species that are invasive elsewhere were regarded as potentially invasive species and were considered for impact assessment. Naturalised species not invasive elsewhere were included in the Uncertainty List.

Casual and not in the wild species were screened for climatic suitability in Spain (see method below). For species climatically suitable somewhere in the country, with a medium to high level of confidence in the likelihood, we checked whether they were invasive elsewhere (Roy et al. 2014). Species that were not climatically suitable and not registered as invasive elsewhere, were included in the Green List (Dehnen-Schmutz 2011), commonly known as the “*white list*” by decision-makers. In contrast, species that were climatically suitable and were invasive elsewhere were regarded as potentially invasive species and thus considered for impact assessment. On the other hand, species that were climatically suitable but not invasive elsewhere and species that were invasive elsewhere but not climatically suitable were included in the Uncertainty List.

Finally, all the species naturalised or casual in Spain, for which we could not find sufficient data about being invasive elsewhere and those for which we have a low level of confidence in the likelihood of climatic suitability or no data at all, were included in the Uncertainty List. This list also includes species not in the wild that are invasive elsewhere rather than Spain, species that are not climatic suitable or species in which the level of confidence in the likelihood of climatic suitability is very low.

In contrast, the Data deficient list includes species not in the wild, with no data on status elsewhere and on climate suitability.

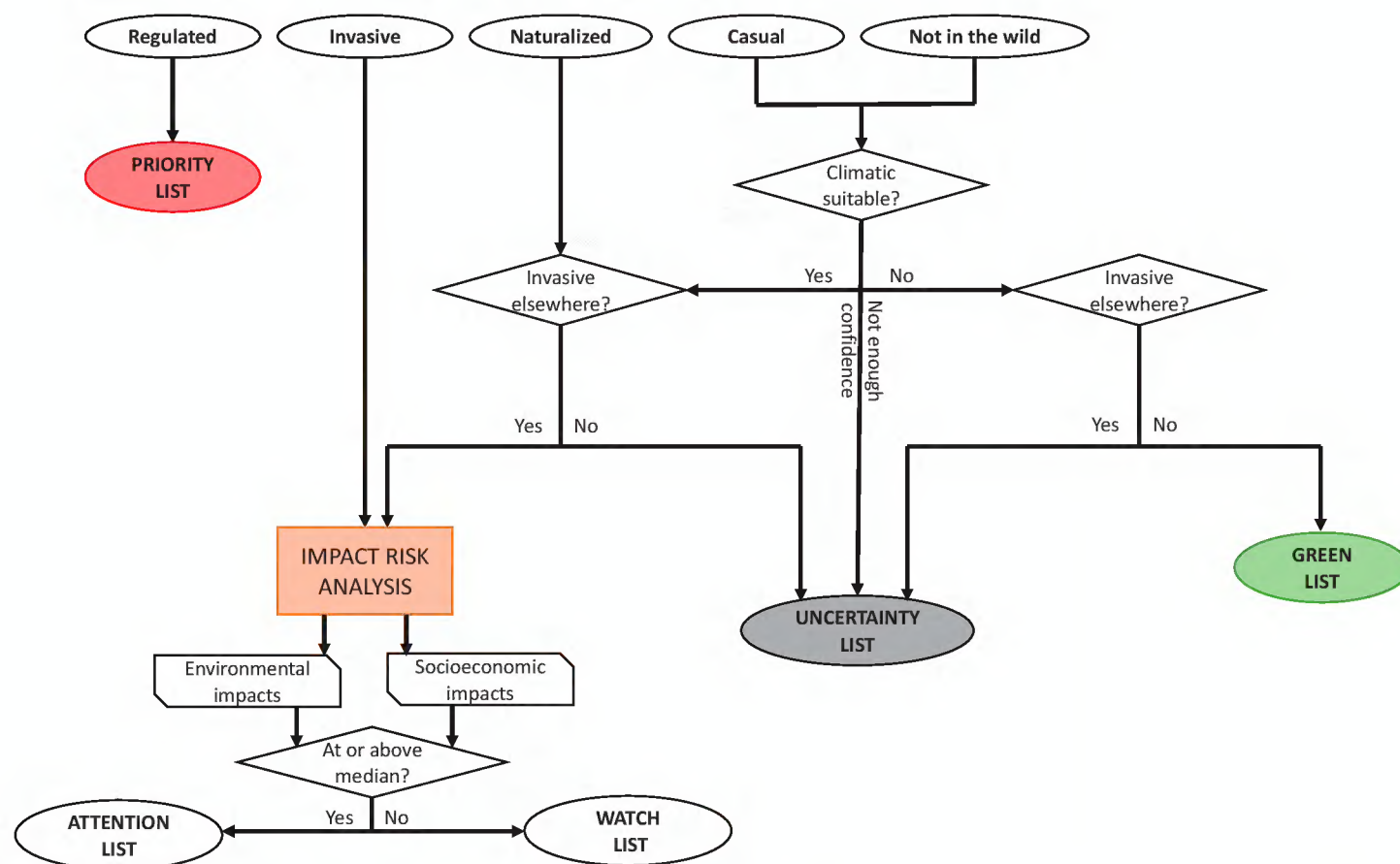


Figure 1. Flow diagram of horizon-scanning of commercial ornamental non-native plant species in Spain and their classification into respective lists. Colour codes correspond to those in Table 1.

Climatic suitability

The climate in Spain is a mosaic of three main climates: Oceanic in the NW, Mediterranean continental in the centre and Mediterranean maritime in the E and S of the country including semi-arid areas (Ninyerola et al. 2005). Furthermore, Spain is a mountainous country, in which elevations over 1500 m a.s.l. are common and the highest peak rises to 3480 m a.s.l. Mountainous areas impose sharp topographical-climatic gradients where these three climatic types gradually change to a Mountain climate, characterised by cold, strong winds and abundant rainfall or snowfall. We know from previous regional analyses that the establishment of non-native species is enhanced in mesic conditions (i.e. intermediate temperature and moisture levels), such as those close to coastal areas (Gassó et al. 2009, González-Moreno et al. 2014).

Precipitation was not considered as a criterion for climatic suitability because Spain has a wide rainfall range. Since our analysis is not spatially explicit, at the regional scale, there are suitable conditions for non-native species to establish and spread (González-Moreno et al. 2014). According to AEMET (2016), the town with the highest rainfall is Vigo (NW Spain), with an average of 1790 mm per year. The climatic station registering the lowest amount is Almería (SE Spain), with an average of 200 mm per year. Therefore, due to this wide range of rainfall in our study area, we did not consider tolerance to drought or waterlogging as climatic classification criteria for the risk of invasion at the country scale.

To follow the precautionary principle, our criteria on temperature suitability were based on the highest absolute minimum and the highest mean of the minimum in the coldest month. This implies that there are many territories in Spain that, having lower

minimum temperatures than the threshold chosen, will be less susceptible to invasion by the species of concern. In this way, we minimise the false negatives that may arise. Thus, we considered a plant to have climatic suitability to survive in Spain if it met two temperature criteria: (1) it can tolerate temperatures below the highest historical absolute minimum temperature in Spain, which was 0.2 °C in Almería (9 February 1935); and (2) it can tolerate temperatures below the highest mean minimum temperature in the coldest month in Spain, which in Tarifa is January at 10.8 °C (mean recorded from data between 1981 to 2010) (AEMET 2016). The air temperature tolerance for each species was consulted in the CABI Invasive Species Compendium (2018).

The level of confidence in the likelihood of climatic suitability was based on the quality of information available. A high level of confidence was assigned if both air temperature values were available; a medium level of confidence was assigned if only one of the temperature values was available but there was information on the species being naturalised or not elsewhere with similar climatic conditions to those in Spain (i.e. Mediterranean or temperate climate); and a low level of confidence was assigned if only one of the temperature values was available or if the species was naturalised or not elsewhere with similar climatic conditions to those in Spain.

Impact assessment

There are different ways to rate impacts in risk assessments. Some are based on their significance and intensity, some on the number of impacts (see table 3 in Vilà et al. 2019). To quantify the intensity of impacts requires a throughout screening of all the scientific literature, an aim that was above our man-power capacity. As we had many species to assess and our approach is by Horizon-scanning, we identified a broad range of potential impact types, including socioeconomic impacts. For each invasive or potentially invasive species, we assigned binary scores (yes/no) to the 11 potential impact mechanisms on the environment, following Blackburn et al. (2014): competition, hybridisation, disease transmission, parasitism, poisoning, toxicity and allelopathy, biofouling, interaction with other invasive non-native species, nutrient cycling, physical modification of the habitat, natural succession and disruption to food webs. We also included potential impacts on four socioeconomic aspects: human health (such as allergenic pollen), infrastructures, agriculture and forestry and other sectors (e.g. livestock, domestic animals). The vast majority of the data concerning impacts was retrieved from the CABI Invasive Species Compendium (2018). For cases in which the CABI compendium did not provide sufficient information, the Global Invasive Species Database (Invasive Species Specialist Group 2015) was consulted. Information on pollen allergenicity was found in the Allergome database (Mari et al. 2009).

We compared the numeric results of potential environmental (0–11) and socioeconomic (0–4) impacts between the different invasion status groups of non-native species (i.e. not in the wild, casual, naturalised and invasive). We used R software to perform a multiple comparison using Tukey's range test, fitted in the generalised linear model (glm) by quasi-Poisson regression.

We consider median values for both environmental and socioeconomic impacts as the threshold for the classification between species with a high and low number of impacts. Species with environmental or socioeconomic impacts at or above the thresholds were included in the Attention List, while species with both environmental and socioeconomic impacts below the threshold formed the Watch List.

Societal interest analysis of Attention List species

Google is currently the most popular information search engine (Purcell et al. 2012) and it is quite useful for forecasting consumption and commerce (Vosen and Schmidt 2011). Google Trends (<http://trends.google.es>) has turned out to be a valuable tool to measure the level of interest of internet users on topics, species, events, questions etc., based on keywords and thus it has already been applied for this purpose in other research (Vosen and Schmidt 2011, Burivalova et al. 2018). Google Trends provides monthly data in a defined temporal range of regional trends of five keywords at a time, always relative to the highest value which is set to 100. We used Google Trends to analyse the level of interest of Spanish users in the Attention List species. We are aware that a species ranking high in interest does not necessarily mean that users are more interested in purchasing them. The reasons behind the searches for these species are not known, but they indicate how popular the species are in society in general.

To standardise those relative values, we used the R pack “gtrendsR” v. 1.4.2. We first made a systematic examination of the scientific names of every species listed in the Attention List in the temporal range from January 2004 to December 2016 to identify the species with the highest trend value. We used the scientific names to standardise our search; some species consulted do not have vernacular names in Spanish and some others may have different names. As the Google Trends tool allows entering 5 keywords at a time, we carried out a first examination forming one initial group of five species to analyse and taking the highest value species in this first group. Then, we compared this highest ranked species with the next four species and again selected the species with the highest value in this new group. Systematically repeating this algorithm with the rest of the species allowed us to identify the species with the highest trend value, *Robinia pseudoacacia*. The highest value for this species is set equal to 100 and this was assigned as our control species. Then, in a second systematic consultation of Google Trends, we obtained the trend data for the rest of the species by comparing each one with the control, in order to standardise the values.

For each species, we obtained a standard trend value (STV) as the highest value of the monthly trend in the complete temporal range of each species, relative to the optimal value of 100 of the control species. After that, we also performed a systematic consultation of Google Trends for the species in the Green List and the Priority List.

We compared differences in STV of the Attention List species across the different invasion status groups of species within the list (i.e. not in the wild, casual, naturalised

and invasive). We used R software to perform a multiple comparison using Tukey's range test, fitted in the generalised linear model (glm) by quasi-Poisson regression. We also compared the STV of the species in the Priority list and the Green list, in order to check whether the STV index correlates with invasion itself.

Invasion risk assessment of Attention List species

We used an adaptation of the invasion risk assessment (WRA) protocol (Pheloung et al. 1999) for Spain (Gassó et al. 2010) in order to rank the species in the Attention list. The WRA scores range from -14 (benign species) to 29 (maximum risk). Three levels of invasion risk were considered: rejected, species likely to be high risk (score > 6); accepted, species with a low score (< 1); and species that need further evaluation, those with intermediate scores (1–6).

We compared the scores of the WRA of the Attention List species across the different invasion status groups of species within the list (i.e. not in the wild, casual, naturalised and invasive). We used R software to perform a multiple comparison using Tukey's range test, fitted in the generalised linear model (glm) by quasi-Poisson regression.

Prioritisation of Attention List species

We calculated a Priority Index for each species in the Attention list based on impact assessment, WRA score and STV according to the following equation:

$$PI_i = \left(\frac{100 \times E_i}{11} + \frac{100 \times S_i}{4} + \frac{100 \times WRA_i}{29} + STV_i \right) / 4$$

where: PI_i = Priority Index for species i ; E_i = number of environmental impacts for species i ; S_i = number of socioeconomic impacts for species i ; WRA_i = Weed Risk Assessment score for species i ; STV_i = Standard Trend Value for species i .

The impact factors were relative to the 11 environmental and 4 socioeconomic impacts which represent the maximum possible impacts in the assessment. The WRA-factor was relative to 29, which is the maximum possible value in the WRA protocol. The STV is already represented as a percentage and thus no conversion is needed.

Within each invasion status group, we listed species in decreasing order of their Priority Index and highlighted those with a Priority Index at or above the median.

Data resources

The data underpinning the analysis, reported in this paper, are deposited in the Zenodo repository at <https://doi.org/10.5281/zenodo.3367257> (Bayon and Vilà 2019).

Results

Of the 914 taxa identified to species, 199 were native to Spain and 15 were archaeophytes. Of the 700 remaining non-native species, we did not find sufficient information on invasion status, climatic suitability or invasiveness elsewhere for 430 species (Data deficient list; Appendix 4) in the consulted databases (Invasive Species Specialist Group 2015; CABI 2018). For the remaining 270 non-native species, 71 taxa were not in the wild, 99 were casual, 70 naturalised and 30 invasive in Spain. Of the invasive species in Spain, eight are regulated by the Spanish Catalogue of Non-native Invasive Species (BOE 2013) and one of them, *Pennisetum setaceum*, is also regulated by the List of Invasive Alien Species of Union Concern (2016, 2017).

Nineteen species not in the wild, 30 casual and 24 naturalised species are climatically suitable and invasive elsewhere and thus considered potential invaders. These species, in addition to the 22 already invasive non-regulated species, were assessed for impact (Table 1).

Impact Assessment

We assessed the potential impact of the above-mentioned 19 not in the wild, 30 casual, 24 naturalised and 22 invasive species that are climatically suitable and invasive elsewhere. The global median value for environmental impacts was three and the median for socioeconomic impacts was one. Therefore, species with impacts at or above these values were included in the Attention List. This included eleven not in the wild (58%), 22 casual (73%), 20 naturalised (83%) and 15 invasive species (68%). We did not find significant differences in the number of environmental or socioeconomic impacts across any pair of species status groups (Fig. 2).

Within each invasion status, the species with the highest number of environmental impacts included the invasive *Robinia pseudoacacia* (7), *Agave sisalana* (6) and *Elaeagnus angustifolia* (6); the naturalised *Ficus pumila* (7), *Ficus rubiginosa* (6), *Lupinus polyphyllus* (6) and *Sansevieria trifasciata* (6); the casual *Wisteria sinensis* (8) and *Grevillea robusta* (7); and the not in the wild *Nymphaea odorata* (7).

Species with the highest number of socioeconomic impacts were the invasive *Robinia pseudoacacia* (3), *Acacia longifolia* (3), *Eucalyptus globulus* (3) and *Lantana camara* (3); the naturalised *Lupinus polyphyllus* (3), *Rhus typhina* (3) and *Tagetes minuta* (3); the casual *Miscanthus sinensis* (3), *Portulaca oleracea* (3) and *Sesbania punicea* (3); and the not in the wild *Allamanda cathartica* (3).

Species listing

The 270 non-native species with available data were classified into the following five lists:

The Priority List contains eight regulated invasive species that were still commercially available in nurseries (Table 2).

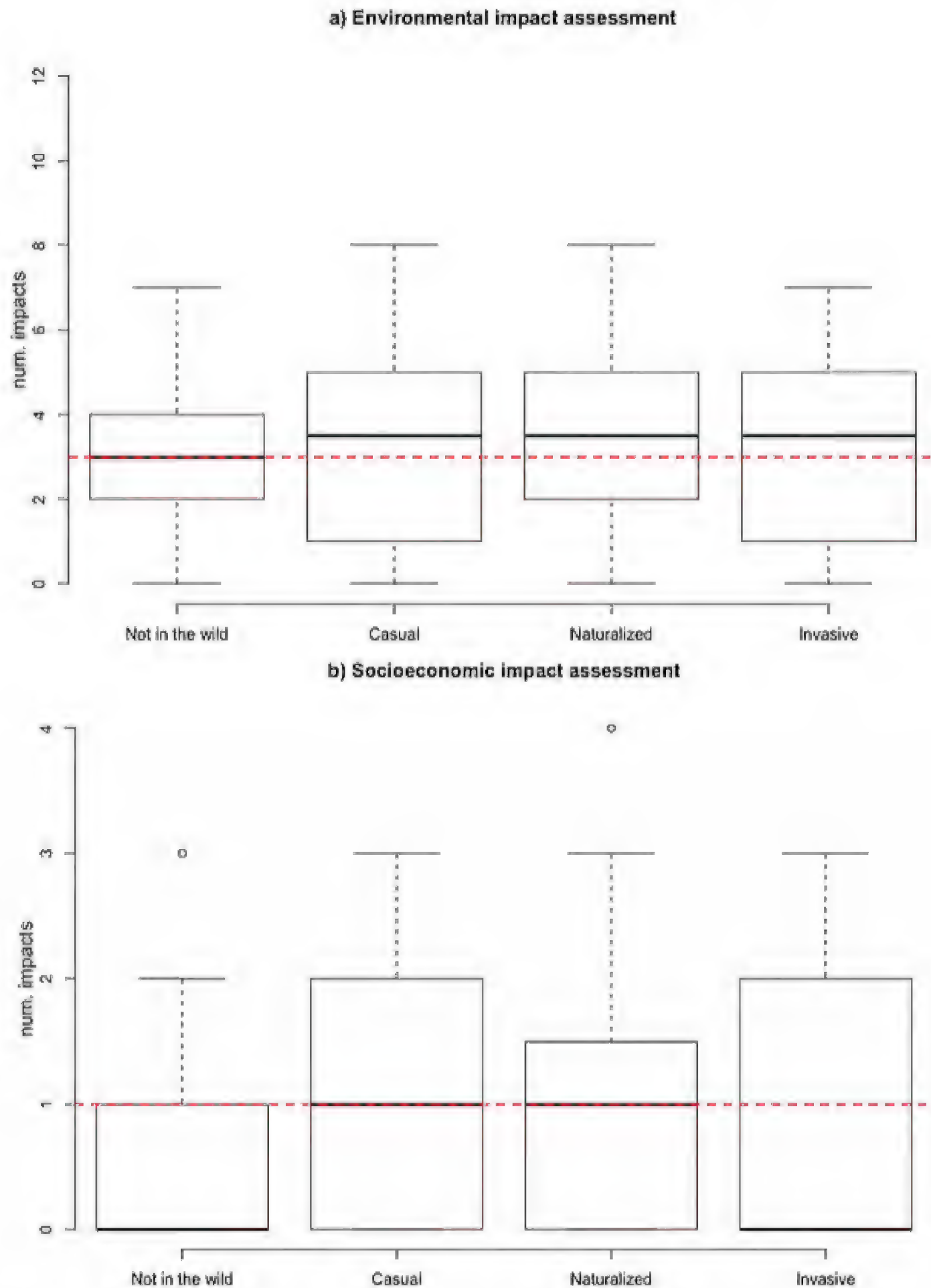


Figure 2. Environmental (a) and socioeconomic (b) impacts of invasive and potentially invasive ornamental plant species. P-values for Tukey's range tests for environmental impacts: not in the wild – casual: $p = 0.833$; not in the wild – naturalised: $p = 0.498$; not in the wild – invasive: $p = 0.926$; casual – naturalised: $p = 0.904$; casual – invasive: $p = 0.997$; naturalised – invasive: $p = 0.845$. P-values for Tukey's range tests for socioeconomic impacts: not in the wild – casual: $p = 0.790$; not in the wild – naturalised: $p = 0.526$; not in the wild – invasive: $p = 0.916$; casual – naturalised: $p = 0.947$; casual – invasive: $p = 0.994$; naturalised – invasive: $p = 0.875$. Dashed red line represents the global median of impacts and the threshold for species in the Attention List (at and above the line, Table 3) and Watch List (below the line, Appendix 2)

Table 1. Classification of commercial ornamental plant taxa in Spain according to their invasion status and climatic suitability. Colour codes correspond to those in Fig 1: Priority List (red, Table 2), Impact Risk Analysis (orange), Green List (green, Table 4) and Uncertainty List (grey, Appendix 3).

	N	Climatic suitable	Not Climatic suitable	Low confidence in likelihood on climatic suitability	Not enough information about climatic suitability	Invasive elsewhere	Not invasive elsewhere
Total taxa in nurseries	1036						
Taxa excluded	122						
Total species listed	914						
Native	199						
Archeophyte	15						
Non-native (non-archeophyte)	700						
Invasive – Regulated	8						
Invasive – Not Regulated	22						
Naturalised	70					24	46
Casual	100	36	2	4	58		
Casual – Climatic Suitable						30	6
Casual – Not Climatic Suitable						1	1
Not in the wild	71	34	10	27			
Not in the wild – Climatic Suitable						19	15
Not in the wild – Not Climatic Suitable						4	6
Data deficient	430						

Table 2. Priority List. Includes invasive species regulated by the Spanish Catalogue of Non-native Invasive Species (BOE 2013) or the List of Invasive Alien Species of Union Concern (European Commission 2016, 2017). Native distribution: Afr: Africa; As: Asia (Temperate); Aus: Australia; NAm: North America; SAm: South and Central America.

Species	Family	Native distribution	Regulated in Spain	Regulated in EU
<i>Acacia dealbata</i>	Fabaceae	Aus	Yes	No
<i>Agave americana</i>	Agavaceae	SAm	Yes	No
<i>Ailanthus altissima</i>	Simarubaceae	As	Yes	No
<i>Buddleja davidii</i>	Scrophulariaceae	As	Yes	No
<i>Cortaderia selloana</i>	Poaceae	SAm	Yes	No
<i>Opuntia ficus-indica</i>	Cactaceae	NAm	Yes	No
<i>Pennisetum setaceum</i>	Poaceae	Afr	Yes	Yes
<i>Tradescantia fluminensis</i>	Commelinaceae	SAm	Yes	No

The Attention List (Table 3) is composed of 68 species, including 11 not in the wild, 22 casual, 20 naturalised and 15 invasive.

The Watch List contains 27 species: eight not in the wild, eight casual, four naturalised and seven invasive, but below the threshold for environmental and socio-economic impacts (Appendix 2).

The Green List is represented by only seven species: one casual and six not in the wild taxa that are not climatically suitable nor invasive elsewhere (Table 4). Finally, the Uncertainty List was formed by 161 species, in which: 46 are not in the wild (27 with low confidence on climatic suitability, 15 not invasive elsewhere but climatically

Table 3. Attention List. Includes all invasive and potentially invasive species with ≥ 3 environmental or ≥ 1 socio-economic potential impacts, classified as: a) not in the wild, b) casual, c) naturalised and d) invasive species, presented in decreasing Priority Index order. Native distribution: Afr: Africa; As: Asia (Temperate); AT: Asia (Tropical); Aus: Australia; Eur: Europe; NAm: North America; Pac: Pacific; SAm: South and Central America. Weed Risk Assessment (WRA): scores 1–6 indicate that the species needs further evaluation; scores > 6 indicate that the species is rejected. STV: Standard Trend Value (0-100). Priority Index is calculated following the equation: $\text{Priority index} = ((100 \times Ei) / 11 + (100 \times Si) / 4 + (100 \times WRA) / 29 + STV) / 4$ where: Ei = environmental impacts; Si = socioeconomic impacts. * Species with Priority Index ≥ 35 have been highlighted with an asterisk.

	Family	Native distribution	Impacts Environment	Socio- economics	WRA Score	WRA Evaluation	STV	Trends Evaluation	Prior. Index
a) Species not in the wild									
<i>Cinnamomum camphora</i> *	Lauraceae	As	4	2	17	Reject	35	Less Interesting	45
<i>Cotoneaster horizontalis</i> *	Rosaceae	As, AT	3	1	26	Reject	37	Less Interesting	45
<i>Physalis angulata</i> *	Solanaceae	NAm, SAm, Pac	4	2	22	Reject	0	Not Interesting	41
<i>Allamanda cathartica</i> *	Apocynaceae	SAm	4	3	11	Reject	0	Not Interesting	37
<i>Nymphaea odorata</i> *	Nymphaeaceae	NAm	7	2	9	Reject	0	Not Interesting	36
<i>Leptospermum scoparium</i> *	Myrtaceae	Aus	3	1	13	Reject	43	Less Interesting	35
<i>Cornus sericea</i>	Cornaceae	NAm	4	1	22	Reject	0	Not Interesting	34
<i>Berberis thunbergii</i>	Berberidaceae	As	4	1	12	Reject	27	Less Interesting	32
<i>Alocasia macrorrhizos</i>	Araceae	AT	4	0	13	Reject	0	Not Interesting	20
<i>Euonymus fortunei</i>	Celastraceae	As	4	0	7	Reject	0	Not Interesting	15
<i>Archontophoenix cunninghamiana</i>	Arecaceae	Aus	4	0	4	Evaluating	0	Not Interesting	13
b) Casual species									
<i>Portulaca oleracea</i> *	Portulacaceae	Afr, EUr	4	3	15	Reject	54	Interesting	54
<i>Cestrum nocturnum</i> *	Solanaceae	SAm	4	2	9	Reject	80	Very Interesting	49
<i>Wisteria sinensis</i> *	Fabaceae	As	8	2	9	Reject	43	Less Interesting	49
<i>Kalanchoe daigremontiana</i> *	Crassulaceae	Afr	5	1	22	Reject	37	Less Interesting	46
<i>Pinus radiata</i> *	Pinaceae	NAm	3	2	12	Reject	60	Interesting	45
<i>Nandina domestica</i> *	Berberidaceae	As, AT	5	2	9	Reject	43	Less Interesting	42
<i>Casuarina equisetifolia</i> *	Casuarinaceae	Aus	5	2	7	Reject	45	Less Interesting	41
<i>Miscanthus sinensis</i> *	Poaceae	AT	6	3	9	Reject	0	Not Interesting	40
<i>Paulownia tomentosa</i> *	Paulowniaceae	As, AT	4	1	19	Reject	27	Less Interesting	38
<i>Zantedeschia aethiopica</i> *	Araceae	Afr	0	1	15	Reject	70	Interesting	37
<i>Physalis peruviana</i> *	Solanaceae	SAm	5	2	8	Reject	22	Not Interesting	36
<i>Grevillea robusta</i> *	Proteaceae	Aus	7	1	2	Evaluating	45	Less Interesting	35
<i>Sesbania punicea</i> *	Fabaceae	SAm	2	3	13	Reject	0	Not Interesting	35
<i>Gypsophila paniculata</i>	Caryophyllaceae	As, Eur	6	1	6	Evaluating	17	Not Interesting	29
<i>Eugenia uniflora</i>	Myrtaceae	SAm	5	0	18	Reject	0	Not Interesting	27

	Family	Native distribution	Impacts Environment	Socio- economics	Score	WRA Evaluation	STV	Trends Evaluation	Prior. Index
<i>Spiraea japonica</i>	Rosaceae	As, AT	4	0	11	Reject	28	Less Interesting	26
<i>Tecoma stans</i>	Bignoniaceae	NAm, SAm	4	1	11	Reject	0	Not Interesting	25
<i>Prunus serotina</i>	Rosaceae	NAm	6	0	12	Reject	0	Not Interesting	24
<i>Morus nigra</i>	Moraceae	As	3	0	4	Evaluating	45	Less Interesting	22
<i>Eucalyptus sideroxylon</i>	Myrtaceae	Aus	3	0	14	Reject	0	Not Interesting	19
<i>Yucca aloifolia</i>	Agavaceae	NAm	3	1	4	Evaluating	0	Not Interesting	17
<i>Cereus uruguayanus</i>	Cactaceae	SAm	3	0	3	Evaluating	0	Not Interesting	9
c) Naturalised species									
<i>Lupinus polyphyllus</i> *	Fabaceae	NAm	6	3	27	Reject	0	Not Interesting	56
<i>Canna indica</i> *	Cannaceae	SAm	8	1	24	Reject	35	Less Interesting	54
<i>Rhus typhina</i> *	Anacardiaceae	NAm	5	4	15	Reject	0	Not Interesting	49
<i>Phragmites australis</i> *	Poaceae	NAm	2	2	27	Reject	35	Less Interesting	49
<i>Tagetes minuta</i> *	Asteraceae	NAm	4	3	22	Reject	0	Not Interesting	47
<i>Imperata cylindrica</i> *	Poaceae	AT	7	1	24	Reject	0	Not Interesting	43
<i>Ficus pumila</i> *	Moraceae	AT	3	3	5	Evaluating	35	Less Interesting	39
<i>Phoenix canariensis</i> *	Arecaceae	Afr	4	1	6	Evaluating	71	Interesting	38
<i>Melia azedarach</i> *	Meliaceae	AT, Aus	4	0	12	Reject	71	Interesting	37
<i>Psidium cattleianum</i> *	Myrtaceae	SAm	6	1	20	Reject	0	Not Interesting	37
<i>Albizia julibrissin</i>	Fabaceae	As	3	0	14	Reject	62	Interesting	34
<i>Ficus rubiginosa</i>	Moraceae	Aus	6	1	7	Reject	26	Less Interesting	32
<i>Broussonetia papyrifera</i>	Moraceae	As	5	2	2	Evaluating	27	Less Interesting	32
<i>Ziziphus jujuva</i>	Rhamnaceae	As, AT, Aus	5	1	17	Reject	0	Not Interesting	32
<i>Pennisetum villosum</i>	Poaceae	Afr	3	0	25	Reject	0	Not Interesting	28
<i>Sansevieria trifasciata</i>	Asparagaceae	Afr	4	0	12	Reject	35	Less Interesting	28
<i>Bacopa monnieri</i>	Plantaginaceae	NAm, SAm, As, Eur	2	1	16	Reject	10	Not Interesting	27
<i>Adiantum raddianum</i>	Pteridaceae	SAm	3	1	13	Reject	7	Not Interesting	26
<i>Atriplex semibaccata</i>	Amaranthaceae	Aus	3	0	15	Reject	0	Not Interesting	20
<i>Annona cherimola</i>	Annonaceae	SAm	1	1	0	Accepted	0	Not Interesting	9
d) Invasive species									
<i>Robinia pseudoacacia</i> *	Fabaceae	NAm	7	3	15	Reject	100	Very Interesting	73
<i>Lantana camara</i> *	Verbenaceae	SAm	5	3	25	Reject	67	Interesting	68
<i>Eucalyptus globulus</i> *	Myrtaceae	Aus	4	3	21	Reject	35	Less Interesting	55
<i>Acacia longifolia</i> *	Fabaceae	Aus	4	3	23	Reject	0	Not Interesting	48
<i>Acacia saligna</i> *	Fabaceae	Aus	5	1	22	Reject	23	Not Interesting	42
<i>Leucaena leucocephala</i> *	Fabaceae	NAm	5	0	21	Reject	35	Less Interesting	38
<i>Elaeagnus angustifolia</i> *	Elaeagnaceae	As	6	0	21	Reject	19	Not Interesting	36
<i>Lonicera japonica</i> *	Caprifoliaceae	As, AT	3	1	14	Reject	39	Less Interesting	35

	Family	Native distribution	Impacts Environment	Socio-economics	WRA Score	WRA Evaluation	STV	Trends Evaluation	Prior. Index
<i>Agave sisalana</i> *	Agavaceae	SAm	6	2	10	Reject	0	Not Interesting	35
<i>Psidium guajava</i>	Myrtaceae	NAm	4	1	19	Reject	0	Not Interesting	32
<i>Gleditsia triacanthos</i>	Fabaceae	NAm	4	0	10	Reject	41	Less Interesting	28
<i>Phormium tenax</i>	Xanthorrhoeaceae	Pac	3	0	10	Reject	35	Less Interesting	24
<i>Bidens aurea</i>	Asteraceae	NAm	1	2	5	Evaluating	18	Not Interesting	24
<i>Stenotaphrum secundatum</i>	Poaceae	Afr	5	0	13	Reject	0	Not Interesting	23
<i>Pasiflora caerulea</i>	Passifloraceae	SAm	3	0	6	Evaluating	0	Not Interesting	12

Table 4. Green List. Includes non-native non-invasive species with very low invasion potential. Native distribution: As: Asia (Temperate); AT: Asia (Tropical); SAm: South and Central America. Status in Spain: N: Not in the wild, C: Casual.

Species	Family	Native distribution	Status in Spain
<i>Averrhoa carambola</i>	Oxalidaceae	AT	N
<i>Celosia argentea</i>	Amaranthaceae	AT	N
<i>Ficus benjamina</i>	Moraceae	AT	N
<i>Mangifera indica</i>	Anacardiaceae	As – AT	N
<i>Nelumbo nucifera</i>	Nelumbonaceae	AT	N
<i>Pogostemon helferi</i>	Lamiaceae	AT	N
<i>Senna corymbosa</i>	Fabaceae	SAm	C

suitable, four not climatically suitable but invasive elsewhere), 69 are casual (4 with low confidence on climatic suitability, 58 with no available information on climatic suitability, six not invasive elsewhere but climatically suitable and one not climatically suitable but invasive elsewhere) and 46 are naturalised not invasive elsewhere (Appendix 3).

Societal interest analysis of Attention List species

In the Google Trends systematic examination of the 68 Attention List species, maximum trend values were observed for *Robinia pseudoacacia* – March 2004 – and therefore we used this record as our control species.

Within the Attention list, the most noteworthy species (higher STV) included: the invasive *Robinia pseudoacacia* (100) and *Lantana camara* (67); the naturalised *Phoenix canariensis* (71) and *Melia azedarach* (71); the casual *Cestrum nocturnum* (80) and *Zantedeschia aethiopica* (70); and, far from the previous groups, the not in the wild *Leptospermum scoparium* (43). Complete results of the STV analysis are shown in Table 3. There were no significant differences in STV between any pair of invasion status groups of species (Fig. 3). Similarly, there were no differences between the species in the Priority list and the Green List ($p=0.967$).

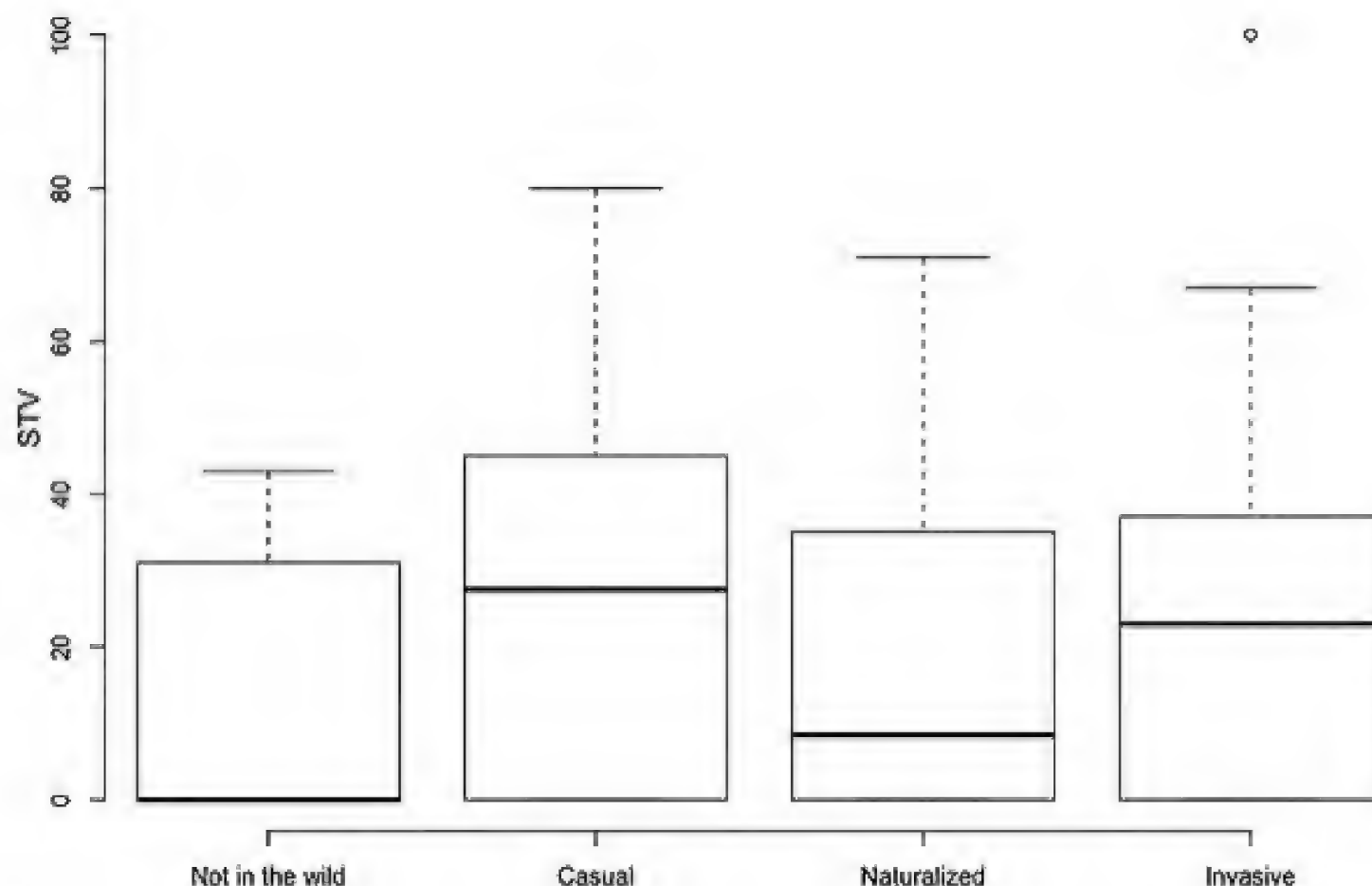


Figure 3. Society interest in ornamental non-native plant species classified by their invasion status. STV: Standard Trend Value. P-values for Tukey's range tests: not in the wild – casual: $p = 0.373$; not in the wild – naturalised: $p = 0.783$; not in the wild – invasive: $p = 0.436$; casual – naturalised: $p = 0.794$; casual – invasive: $p = 1$; naturalised – invasive: $p = 0.860$.

Invasion risk assessment of Attention List species

In the WRA, all species in the Attention List were rejected, except for 11 that required further evaluation and only one, *Annona cherimola*, that was accepted (Table 3).

Within each invasion status, the highest WRA scores were for the invasive *Lantana camara* (25), *Acacia longifolia* (23), *Acacia saligna* (22), *Elaeagnus angustifolia* (21), *Eucalyptus globulus* (21) and *Leucana leucocephala* (21); the naturalised *Phragmites australis* (27), *Lupinus polyphyllus* (27), *Pennisetum villosum* (25), *Canna indica* (24) and *Imperata cylindrica* (24); the casual *Kalanchoe daigremontiana* (22), *Pawlonia tomentosa* (19) and *Eugenia uniflora* (18); and the not in the wild *Cotoneaster horizontalis* (26), *Cornus sericea* (22) and *Physalis angulata* (22). For every invasion status, the species requiring further evaluation accounted for less than 25%. There were no significant differences in WRA scores between any pair of invasion status groups of species (Fig. 4).

Prioritisation of Attention List species

The median value of Priority Indices was 35. Species with a Priority Index ≥ 35 are highlighted in Table 3. Within each invasion status, the highest Priority Indices in invasive species were found for *Robinia pseudoacacia* (73), *Lantana camara* (68) and

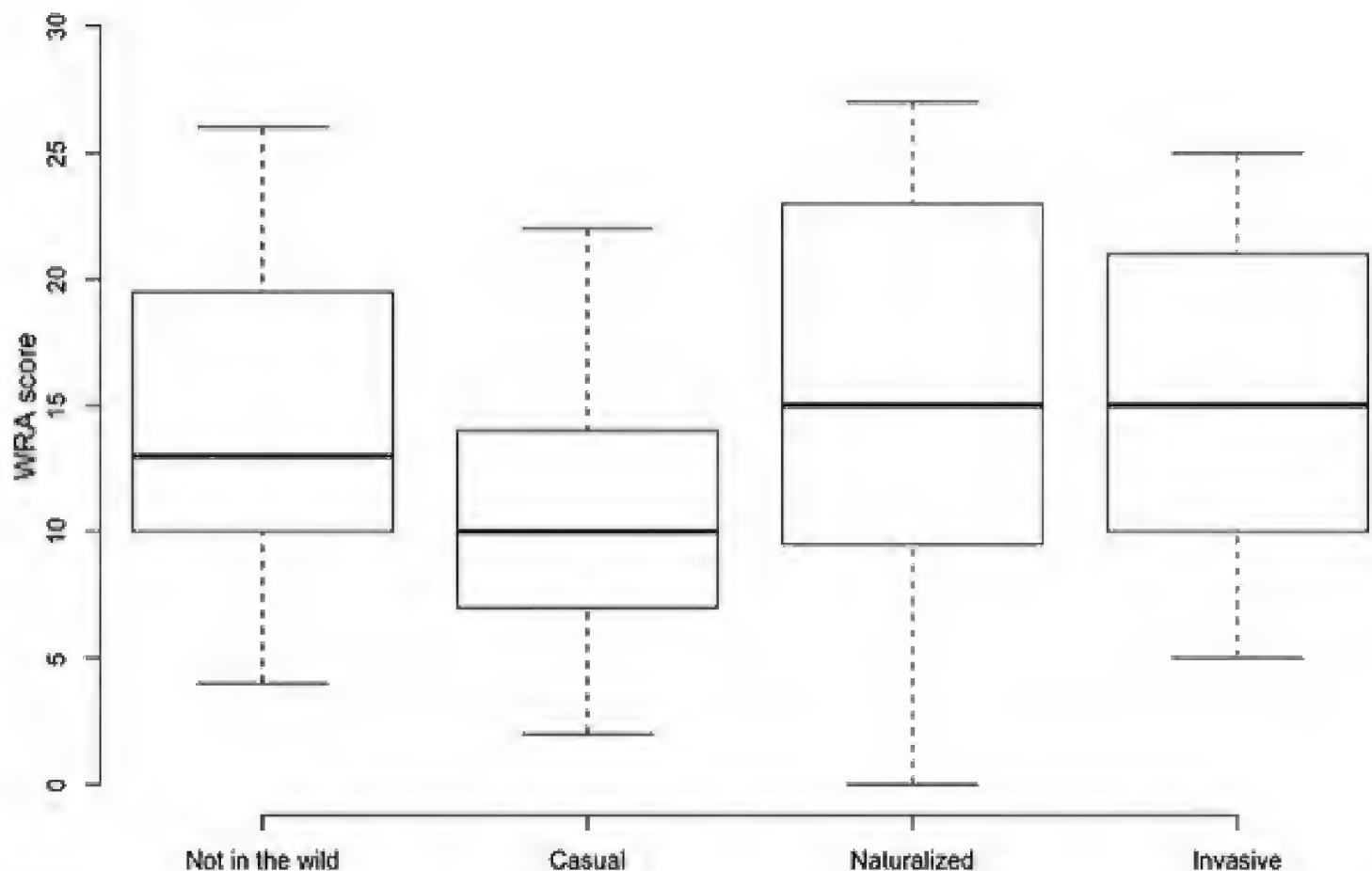


Figure 4. Weed risk assessment (WRA) score in ornamental non-native plant species classified by their invasion status in Spain. P-values for Tukey's range tests: not in the wild – casual: $p = 0.392$; not in the wild – naturalised: $p = 0.983$; not in the wild – invasive: $p = 0.951$; casual – naturalised: $p = 0.101$; casual – invasive: $p = 0.086$; naturalised – invasive: $p = 0.997$.

Eucalyptus globulus (55); in naturalised species *Lupinus polyphyllus* (56) and *Canna indica* (54); in casual species *Portulaca oleracea* (54), *Cestrum nocturnum* (49) and *Wisteria sinensis* (49); and in not in the wild species *Cinnamimum camphora* (45) and *Cotoneaster horizontalis* (45). There were no significant differences between any pair of invasion status groups of species (Fig. 5).

Discussion

Nurseries and the commercial introduction of non-native plant species are the main deliberate pathways for plant invasions (Van Kleunen et al. 2018). Some of the most harmful invasive plant species in the wild are non-native species introduced for commercial purposes (Hulme 2007). In Spain, non-native plants represent the vast majority of species sold by nurseries (77%) and 30 of these species have been reported as invasive in the peninsular territory of Spain. The regulation of non-native invasive plant species is necessary. However, nurseries often do not fully comply with commercial restrictions (Wirth et al. 2004; Cronin et al. 2017; Touza et al. 2014). Besides the Spanish (BOE 2013) and European (European Commission 2016, 2017) regulations on non-native invasive species and similar to what happens in other countries, there are eight regulated species that, although being regulated, were still commercially available

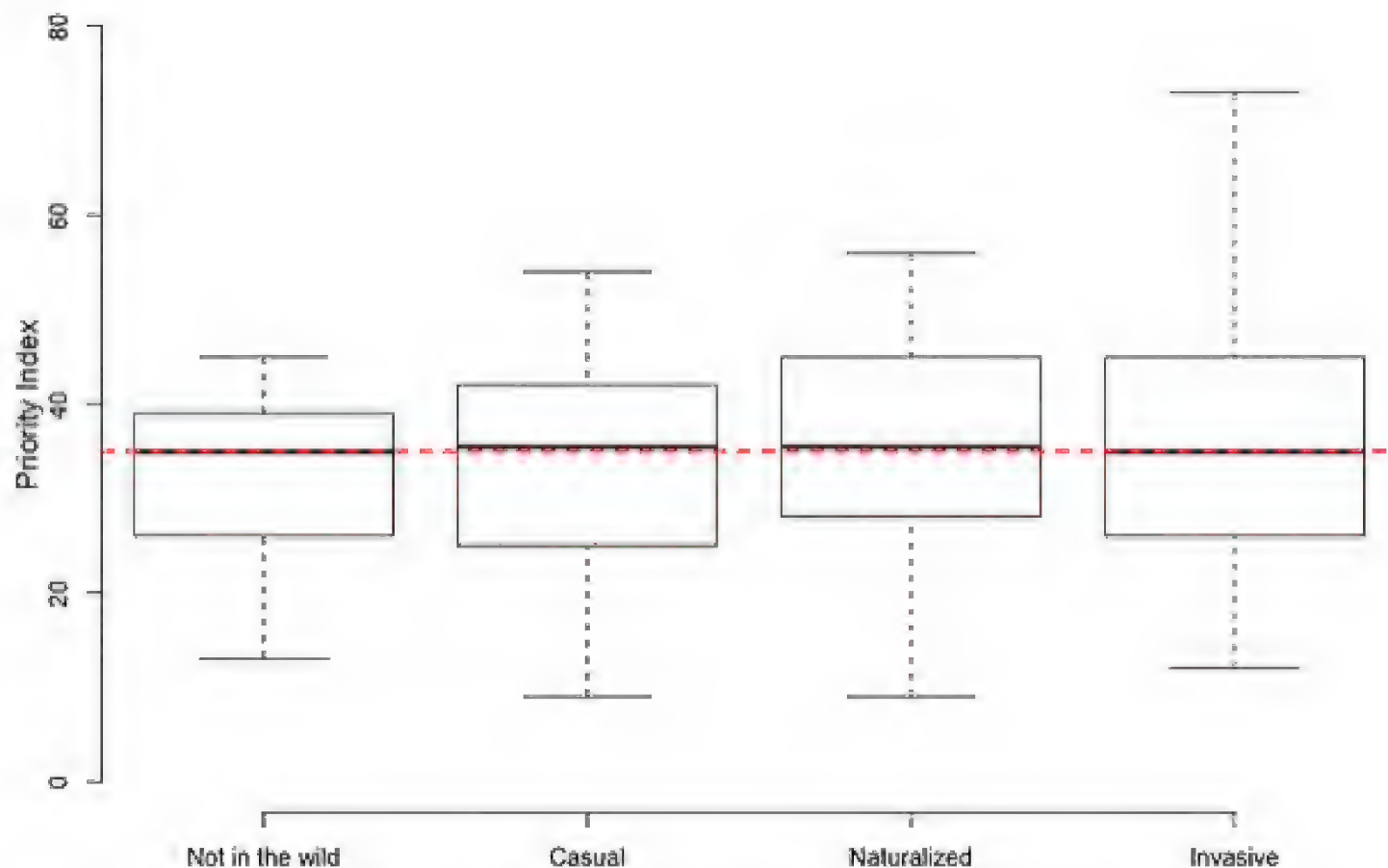


Figure 5. Priority Index in ornamental non-native plant species classified by their invasion status in Spain. P-values for Tukey's range tests: not in the wild – casual: $p = 0.981$; not in the wild – naturalised: $p = 0.860$; not in the wild – invasive: $p = 0.633$; casual – naturalised: $p = 0.958$; casual – invasive: $p = 0.748$; naturalised – invasive: $p = 0.953$. Dashed red line represents the global median of Priority Index (=38). Species at or above this line should be considered in prioritisation, as shown in table 3.

in the country at the time of this study (Appendix 1), as indicated in the Priority List. One of them, *Pennisetum setaceum*, was also been included under European regulation, although this inclusion is more recent than the study of the nurseries for this study. Therefore, there is a pressing need to enforce the current legislation, as well as to raise public awareness to prohibit the trade of these species.

Furthermore, because the deliberate transport, commerce and planting of non-native plant species can be controlled, all the invasive and potentially invasive species compiled into the Attention List could be considered for regulation, following the advice of the European Parliament and Council (2014). While some of these species have been introduced to provide an immediate economic benefit, such as *Eucalyptus globulus* and other species of the same genus (Touza et al. 2014), their impacts on the environment, as well as on some human activities besides the forestry sector, suggest that their regulation should be considered. In addition, the costs derived from the control of invasive species can be quite significant (Pimentel et al. 2005) and are not compensated for by their economic benefits.

The levels of potential impacts of species in the Attention List are independent of their invasion status in Spain. That is, current non-invasive species have the potential to cause as many impacts as invasive species. This result supports previous empirical studies indicating that invasiveness does not always translate to impacts (Ricciardi

and Cohen 2007). Despite the fact that some of these species were introduced a long time ago and are already invasive, such as *Ailanthus altissima* introduced into Spain in 1818 or *Acacia dealbata* in 1824 (Sanz Elorza et al. 2004), others have possibly been introduced recently as ornamental plants and thus have not had enough time for establishment and dispersal (Pemberton and Liu 2009). As a precautionary measure to avoid their impacts, there is a need to prevent the introduction of any non-native species listed in the Attention List and to conduct a complete risk assessment to study the possibility of their being regulated.

As the threshold number of environmental and socioeconomic impacts required for a species to be included or not in the Attention List is based on median values, it may exclude some species that have high risks of invasion despite a low number of impact types or species with still unknown impacts. In fact, the Watch List contains species that are well known to be invasive elsewhere, such as *Acer negundo* or *Eriobotrya japonica*, which cause few, but important, impacts. More detailed research on the potential type of impacts of the species in the Watch List, as well as conducting a WRA for these species, would allow for more adequate prioritisation of these species that are of major concern after those in the Priority and Attention Lists.

We are confident that the potential invasion of Attention List species is robust given the positive results of the WRA, in which only one of the 68 species listed was classified as accepted (i.e. low invasion risk). The proportion of species rejected by the WRA was very high and similar in all status groups of species, with a likely low incorporation of false positives (Andreu and Vilà 2010). Furthermore, our WRA analysis warns that species which are not in the wild, still have the potential to become invasive, reaching scores as high as those of already naturalised or invasive plants.

Likewise, with our analysis on the STV, we cannot infer causality between societal interest and increased commerce. In fact, the STV is not a good predictor of invasion status; the absence of differences between STV of the species in the Priority list and the Green list shows that the STV is not related with invasion. Nevertheless, greater interest, as reflected in Google statistics, can still be an indicator of increased consumption and trade (Vosen and Schmidt 2011) and greater interest might promote greater propagule pressure and greater potential to become established (Dehnen-Schmutz et al. 2007a; Johnston et al. 2009; Blackburn et al. 2013; García-Díaz et al. 2015). Thus, we think that the STV continues to have value, not as a predictor of invasion, but as a factor to be considered during prioritisation of the species within each invasion group.

Our approach is similar to previous Horizon-scanning analyses for non-native species (Roy et al. 2014, Roy et al. 2019) with the differences being that, in our study case, all the species are already in the region of analysis and the scoring is based on more parameters than just their potential to establish and cause impacts. We provide a Priority Index that includes the risk of invasion, the level of potential impacts and the popularity of the species. Therefore, it offers an integrative score that may be of interest to environmental administrations and management services as a valuable tool to support decision-making. The homogeneity in the Priority Index across the invasion status groups of species confirms that the potential for invasion and the impact

risks are independent of the actual invasion status of the species (Roberts et al. 2011; Gassó et al. 2010). Therefore, this index may even be useful for identifying current non-invasive species that, even if not in the wild, are potentially invasive. Indeed, our species Prioritisation List has already been used to identify species with the potential to be invasive in Gibraltar, an overseas territory of the United Kingdom which buys all its ornamental plants from neighbouring Spain according to the UKOTs Horizon Scanning and Biosecurity Workshop that took place on 21–24 January 2019 (K. Bensusan, pers. Com).

We also generated an Uncertainty List composed of species that probably do not represent an immediate invasion risk. For fifty-six percent of the species listed, we lack sufficient confidence in the likelihood of climatic suitability (or we have no information about it). Even if the species in the Uncertainty List do not become established in Spain due to their climatic requirements, or they are not invasive elsewhere, we need to be aware that these two criteria can change over time. For example, a particular climate change scenario could cause climatically unsuitable species to become suitable in the future (Mainka and Howard 2010).

Unfortunately, we could not find information on the status, invasive potential and climatic suitability of 61% of the non-native species sold in nurseries. There is a worrying possibility that the Data Deficient List includes some potentially invasive species that are not considered in the two major databases consulted (CABI Datasheets 2018; Invasive Species Specialist Group 2015). Additional research, as well as consultation of the primary literature, is needed to allow reclassifying species from the Data Deficient List, a task that would require the expertise of a larger team of scientists (Roy et al. 2019; González-Moreno et al. 2019). The immediate task would be to use the new available GLONAF database to identify invasive species elsewhere (van Kleunen et al. 2019).

Finally, we provide a Green List of non-native species with very low invasion potential. Promoting preferences for non-invasive species in horticulture can be a valuable endeavour in order to make regulations easier to comply with (Gagliardi and Brand 2007). Involving the horticultural industry in the dissemination of plant invasion risks and in the development of regulations has been shown to be effective (Humair et al. 2014). This Green List can be a starting point for the establishment of voluntary codes of conduct amongst nursery owners (Reichard 2004; Gagliardi and Brand 2007; Robinson et al. 2017). However, it is prudent not to forget that propagule pressure is an important factor determining invasion (Lockwood et al. 2005; 2009; Johnston et al. 2009).

If species in the Green List are planted frequently, in large quantities and in many locations, this scenario can be changed. For this reason, the Green List presented here is short and tentative; further and more in-depth research is needed on the Uncertainty List so as to possibly enlarge this Green List. Planting native species will always be the preferable alternative.

The present research is preliminary in nature and the authors are aware of the clear limitations of the conclusions. However, we consider it can be a very useful and complete tool to establish priorities in long lists of species for which not much information is available and it represents a good starting point for more thorough and detailed risk

analyses that allow the improvement and implementation of new and more efficient forms of regulation of invasive species.

Based on our prioritization list analysis, we provide the following recommendations: 1) there is a need to reinforce the current legislation and implement systems that guarantee its compliance regarding the species of the Priority List; 2) invasive species in the Attention List should be considered for regulation; 3) established, casual and not in the wild species in the Attention List, especially those with higher Priority Index values, should be included in a monitoring programme to prevent future invasions; 4) species in the Watch List should be included in an early warning programme if they are not yet in the wild and monitored if they are already established in a few localities; 5) species in the Uncertainty List require further evaluation in order to be reclassified into Attention, Watch or Green Lists; finally 6) species in Data Deficient List require further information on their status, invasive potential or climatic suitability in order to be reclassified into Attention, Watch or Green lists.

This research also reveals the limited responsibility and awareness by some commercial nurseries regarding the sale of invasive species. A better monitoring and tracking system for the species for sale and more rigorous inspections in nurseries are very necessary (Touza et al. 2014). Citizen awareness through the dissemination of knowledge about invasive non-native species, as well as citizen science projects working with gardeners, can be useful tools to reduce their demand and consumption as suggested in other studies (Reichard 2004; Gagliardi and Brand 2007; Robinson et al. 2017; Dehnen-Schmutz and Conroy 2018). Having a national registry of ornamental plant species available for sale and the requirement of a risk analysis for the introduction of new species in it, is also a recommendation to be considered.

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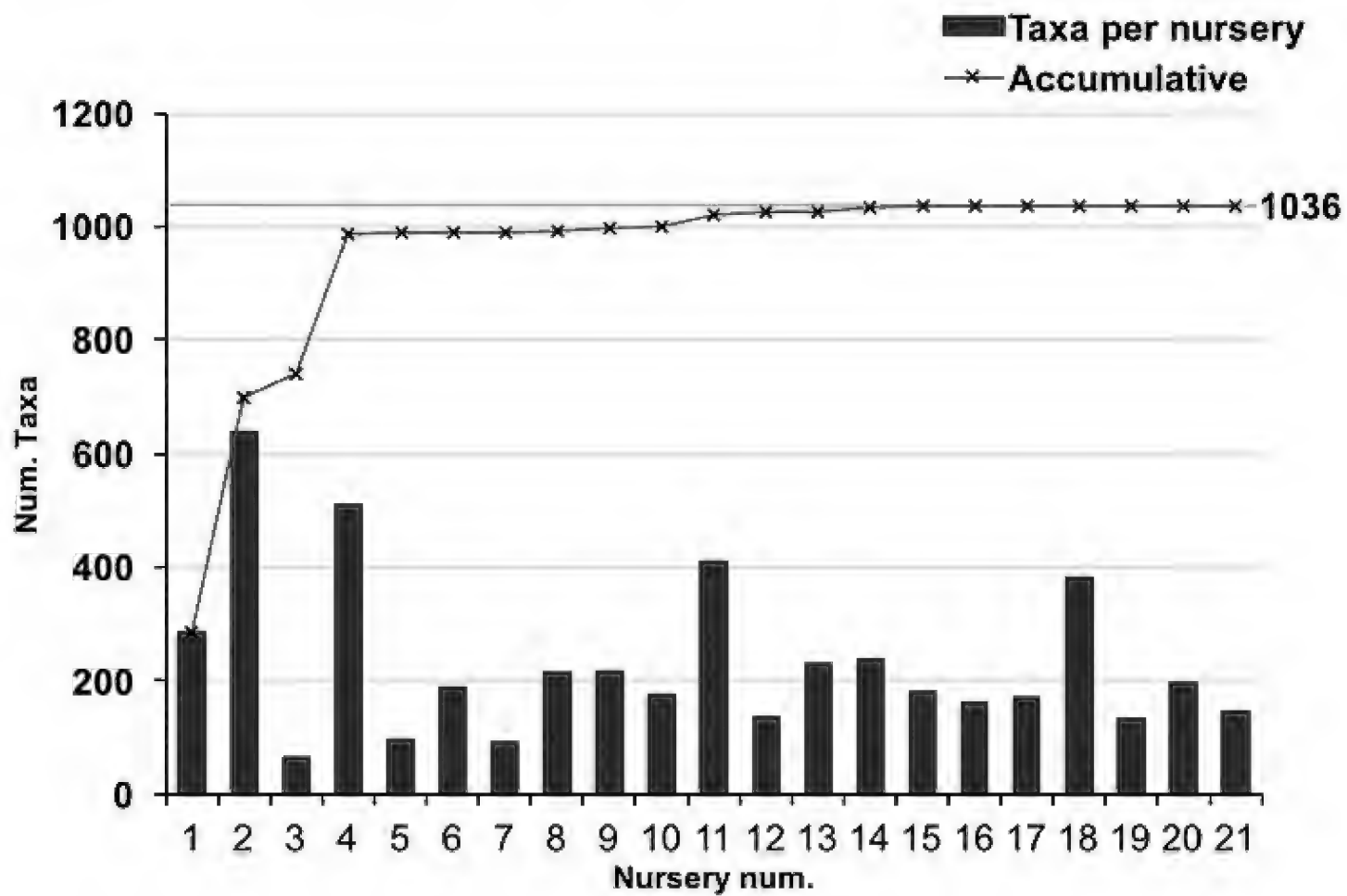
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Appendix I

Table A1. Nurseries. The list of taxa was compiled through the systematic consultation of Spanish nursery catalogs which provide information on plants for sale. As shown in the graph below, the number of taxa did not increase after the 15th catalog was consulted. Our database included a total of 1036 taxa from 21 nurseries. Notice that these nurseries are distributed across all biogeographic regions of mainland Spain.

	Nursery	Source	Access date	Province	Num. taxa
1	Viveros Plantamus	https://plantamus.com	11/12/15	A Coruña	286
2	Viveros Sanchez	http://viverossanchez.com	01/04/16	Guadalajara	638
3	Viveros Maiplant	http://www.maiplant.com	02/23/16	Alicante	66
4	Alberola Viveros	http://www.alberolaviveros.com	02/23/16	Valencia	510
5	Viveros Bargues	http://www.viverosbargues.com	02/24/16	Valencia	97
6	Viveros Rucat	http://www.viverosrucat.es	01/26/16	Madrid	189
7	Viveros Veron	http://viverosveron.com	01/26/16	Zaragoza	92
8	Garden Center Campo Grande	http://www.campogrande.es	01/31/16	Valladolid	214
9	Plantas del Sueve	http://www.delsueve.com	02/01/16	Asturias	217
10	Viveros Urkiondo	http://www.urkiondo.com	02/09/16	Guipuzkoa	174
11	Viveros Barra	http://viverosbarra.es	05/01/16	Leon	410
12	Viveros Coplant	http://www.coplant.es	05/20/16	Pontevedra	137
13	Viveros Borrazas	http://www.viverosborrazas.com	06/11/16	A Coruña	231
14	Viveros Zuaime	http://www.viveroszuaime.es	06/14/16	Granada	238
15	Viveros Sevilla	http://www.viverossevilla.com	06/16/16	Sevilla	180
16	Viveros Ferca	http://viverosferca.com	07/28/16	Ciudad Real	162
17	Viveros Ibañez	http://www.viverosibanez.es	09/20/16	Zaragoza	171
18	Viveros Corma	http://www.corma.es	09/30/16	Barcelona	383
19	Viveros Canós	http://viveroscanos.com	09/30/16	Badajoz	132
20	Viveros Perica	http://viverosperica.com	10/03/16	La Rioja	195
21	Viveros Ametza	http://www.viverosametza.com	10/03/16	Navarra	147



Appendix 2

Table A2. Watch list. The Watch List includes invasive and potentially invasive species with potential impacts below median; classified as: a) not in the wild, b) casual, c) naturalized and d) invasive species. Native distribution: Afr: Africa; As: Asia (Temperate); AT: Asia (Tropical); Aus: Australia; NAm: North America; SAm: South and Center America.

	Family	Native distribution	Impacts	
			Environment	Socioeconomics
a) Species not in the wild				
<i>Berberis darwinii</i>	Berberidaceae	SAm	2	0
<i>Euonymus alata</i>	Celastraceae	As	2	0
<i>Ficus elastica</i>	Moraceae	As	2	0
<i>Fraxinus americana</i>	Oleaceae	NAm	0	0
<i>Gunnera manicata</i>	Gunneraceae	SAm	2	0
<i>Pyrus calleryana</i>	Rosaceae	As, AT	0	0
<i>Thevetia peruviana</i>	Apocynaceae	NAm, SAm	0	0
<i>Zelkova serrata</i>	Ulmaceae	As, AT	0	0
b) Casual species				
<i>Ageratum houstonianum</i>	Asteraceae	SAm	0	0
<i>Aloe vera</i>	Liliaceae	Afr	0	0
<i>Corymbia citriodora</i>	Myrtaceae	Aus	0	0
<i>Erigeron karvinskianus</i>	Asteraceae	SAm	0	0
<i>Lagerstroemia indica</i>	Lythraceae	As, AT	2	0
<i>Salix babylonica</i>	Salicaceae	As	0	0
<i>Salvia microphylla</i>	Lamiaceae	NAm	1	0
<i>Trachycarpus fortunei</i>	Arecaceae	As	1	0
c) Naturalized species				
<i>Alpinia zerumbet</i>	Zigimberaceae	AT	2	0
<i>Berberis aquifolium</i>	Berberidaceae	NAm	1	0
<i>Parthenocissus quinquefolia</i>	Vitaceae	NAm	0	0
<i>Passiflora edulis</i>	Passifloraceae	SAm	2	0
d) Invasive species				
<i>Acer negundo</i>	Aceraceae	NAm	1	0
<i>Cyperus alternifolius</i>	Cyperaceae	Afr	0	0
<i>Eriobotrya japonica</i>	Rosaceae	As	0	0
<i>Eucalyptus camaldulensis</i>	Myrtaceae	Aus	1	0
<i>Oenothera biennis</i>	Onagraceae	NAm	1	0
<i>Pelargonium capitatum</i>	Geraniaceae	Afr	2	0
<i>Tropaeolum majus</i>	Tropaeolaceae	SAm	0	0

Appendix 3

Table A3. Uncertainty list. The Uncertainty List includes non-invasive and potentially non-invasive species which lack sufficient information, or those that do not meet the requirements to be included in the Green List; classified as: a) not in the wild, b) casual, and c) naturalized species. Native distribution: Afr: Africa; As: Asia (Temperate); AT: Asia (Tropical); Aus: Australia; Eur: Europe; NAm: North America; Pac: Pacific; SAm: South and Center America. Invasive elsewhere and climate suitability: Y: yes; N: no; Confidence in the likelihood of climatic suitability: H: high; M: med.

	Family	Native distribution	Invasive elsewhere	Climate suitability	Confidence
a) Species not in the wild					
<i>Agave vivipara</i>	Agavaceae	SAm	Y	Y	L
<i>Anubias barteri</i>	Araceae	Afr	N	N	L
<i>Anubias hastifolia</i>	Araceae	Afr	Y	N	L
<i>Anubias heterophylla</i>	Araceae	Afr	Y	N	L
<i>Bacopa caroliniana</i>	Plantaginaceae	NAm	N	Y	L
<i>Bismarckia nobilis</i>	Arecaceae	Afr	N	N	L
<i>Blyxa japonica</i>	Hydrocharitaceae	NAm	N	Y	H
<i>Brahea armata</i>	Arecaceae	NAm	N	Y	L
<i>Brahea edulis</i>	Arecaceae	NAm	N	Y	L
<i>Butia capitata</i>	Arecaceae	SAm	N	Y	L
<i>Cabomba furcata</i>	Cabombaceae	SAm	N	Y	L
<i>Campanula portenschlagiana</i>	Campanulaceae	Eur	N	Y	H
<i>Carex buchananii</i>	Cyperaceae	Aus	N	Y	L
<i>Chamaedorea seifrizii</i>	Arecaceae	NAm	N	Y	L
<i>Clematis montana</i>	Ranunculaceae	As	N	Y	M
<i>Cordyline australis</i>	Asparagaceae	Aus	N	Y	L
<i>Corymbia ficifolia</i>	Myrtaceae	Aus	N	Y	L
<i>Cotinus coggygia</i>	Anacardiaceae	As	N	Y	H
<i>Cryptostegia madagascariensis</i>	Apocynaceae	Afr	Y	N	H
<i>Cycas revoluta</i>	Cycadaceae	As	N	Y	L
<i>Delonix regia</i>	Fabaceae	Afr	Y	N	H
<i>Euphorbia lactea</i>	Euphorbiaceae	SAm	Y	N	M
<i>Ficus lyrata</i>	Moraceae	Afr	N	Y	M
<i>Ficus microcarpa</i>	Moraceae	Aus	Y	Y	L
<i>Freesia alba</i>	Iridaceae	Afr	N	Y	M
<i>Fuchsia magellanica</i>	Onagraceae	SAm	Y	N	M
<i>Gardenia jasminoides</i>	Rubiaceae	As, AT	N	Y	M
<i>Gaultheria mucronata</i>	Ericaceae	SAm	N	Y	L
<i>Gaura lindheimeri</i>	Onagraceae	NAm	N	Y	M
<i>Geum coccineum</i>	Rosaceae	Eur	N	Y	M
<i>Glossostigma elatinoides</i>	Phrymaceae	Aus	N	Y	H
<i>Lilaeopsis brasiliensis</i>	Apiaceae	SAm	N	Y	L
<i>Liriope muscari</i>	Liliaceae	As, NAm	N	Y	L
<i>Livistona chinensis</i>	Arecaceae	As	Y	N	L
<i>Lonicera pileata</i>	Caprifoliaceae	As	N	Y	L
<i>Loropetalum chinense</i>	Hamamelidaceae	As	N	Y	M
<i>Mayaca fluviatilis</i>	Mayacaceae	SAm	N	Y	L

	Family	Native distribution	Invasive elsewhere	Climate suitability	Confidence
<i>Myoporum tetrandrum</i>	Scrophulariaceae	Aus	N	Y	L
<i>Ophiopogon japonicus</i>	Asparagaceae	As	N	Y	H
<i>Opuntia microdasys</i>	Cactaceae	NAm	N	Y	H
<i>Perovskia atriplicifolia</i>	Lamiaceae	As	N	Y	M
<i>Pittosporum tenuifolium</i>	Pittosporaceae	Pac	N	Y	L
<i>Pogostemon stellatus</i>	Lamiaceae	AT, Aus	N	N	L
<i>Rotala wallichii</i>	Lythraceae	As	N	Y	L
<i>Serenoa repens</i>	Arecaceae	NAm	N	Y	L
<i>Vaccinium corymbosum</i>	Ericaceae	NAm	N	Y	M
b) Casual species					
<i>Acacia baileyana</i>	Fabaceae	Aus	N	NA	NA
<i>Acer campestre</i>	Sapindaceae	Afr, Eur	N	NA	NA
<i>Aloe arborescens</i>	Liliaceae	Afr	N	NA	NA
<i>Aloe maculata</i>	Liliaceae	Afr	N	Y	H
<i>Aloysia citrodora</i>	Verbenaceae	SAm	N	Y	H
<i>Anthriscus cerefolium</i>	Apiaceae	Eur	N	NA	NA
<i>Artemisia dracuncululus</i>	Asteraceae	As, Eur, NAm	N	NA	NA
<i>Brachychiton populneus</i>	Malvaceae	Aus	N	NA	NA
<i>Caesalpinia gilliesii</i>	Fabaceae	SAm	N	NA	NA
<i>Callistemon citrinus</i>	Myrtaceae	Aus	N	NA	NA
<i>Calocedrus decurrens</i>	Cupressaceae	NAm	N	NA	NA
<i>Campsis radicans</i>	Bignoniaceae	NAm	N	NA	NA
<i>Catalpa bignonioides</i>	Bignoniaceae	NAm	N	NA	NA
<i>Catharanthus roseus</i>	Apocynaceae	Afr	N	NA	NA
<i>Cedrus deodara</i>	Pinaceae	As	N	NA	NA
<i>Cedrus libani</i>	Pinaceae	Eur	N	NA	NA
<i>Cercis siliquastrum</i>	Fabaceae	Eur	N	NA	NA
<i>Coffea arabica</i>	Rubiaceae	Afr	N	NA	NA
<i>Crassula ovata</i>	Crassulaceae	Afr	N	Y	M
<i>Cupressus arizonica</i>	Cupressaceae	NAm	N	NA	NA
<i>Cupressus macrocarpa</i>	Cupressaceae	NAm	N	NA	NA
<i>Cydonia oblonga</i>	Rosaceae	Eur	N	NA	NA
<i>Diospyros kaki</i>	Ebenaceae	As	N	NA	NA
<i>Eucalyptus gunnii</i>	Myrtaceae	Aus	N	NA	NA
<i>Euonymus japonicus</i>	Celastraceae	As	N	NA	NA
<i>Euphorbia candelabrum</i>	Euphorbiaceae	Afr	N	NA	NA
<i>Helianthus annuus</i>	Asteraceae	NAm	N	NA	NA
<i>Hibiscus rosa-sinensis</i>	Malvaceae	As	N	NA	NA
<i>Hibiscus syriacus</i>	Malvaceae	As	N	NA	NA
<i>Hyacinthus orientalis</i>	Asparagaceae	Afr, AT	N	NA	NA
<i>Jacaranda mimosifolia</i>	Bignoniaceae	SAm	N	NA	NA
<i>Jasminum nudiflorum</i>	Oleaceae	As	N	NA	NA
<i>Jasminum officinale</i>	Oleaceae	As	N	Y	H
<i>Juglans nigra</i>	Juglandaceae	NAm	N	NA	NA
<i>Koeleruteria paniculata</i>	Sapindaceae	As	N	NA	NA
<i>Lagunaria patersonii</i>	Malvaceae	Aus	N	NA	NA
<i>Larix decidua</i>	Pinaceae	Eur	N	NA	NA

	Family	Native distribution	Invasive elsewhere	Climate suitability	Confidence
<i>Lepidium sativum</i>	Brassicaceae	Afr	N	NA	NA
<i>Ligustrum ovalifolium</i>	Oleaceae	As	N	NA	NA
<i>Lobelia erinus</i>	Campanulaceae	Afr	N	NA	NA
<i>Lycium barbarum</i>	Solanaceae	As	N	NA	NA
<i>Malus domestica</i>	Rosaceae	As	N	NA	NA
<i>Mimosa pudica</i>	Fabaceae	SAm	Y	Y	L
<i>Monstera deliciosa</i>	Araceae	SAm	N	NA	NA
<i>Origanum majorana</i>	Lamiaceae	As, Eur	N	NA	NA
<i>Phytolacca dioica</i>	Phytolaccaceae	SAm	N	NA	NA
<i>Pinus canariensis</i>	Pinaceae	Afr	N	NA	NA
<i>Pinus strobus</i>	Pinaceae	NAm	N	NA	NA
<i>Pistacia vera</i>	Anacardiaceae	As, Eur	N	NA	NA
<i>Pittosporum tobira</i>	Pittosporaceae	As	N	NA	NA
<i>Plumbago auriculata</i>	Plumbaginaceae	Afr	N	NA	NA
<i>Populus simonii</i>	Salicaceae	As	N	NA	NA
<i>Prunus armeniaca</i>	Rosaceae	NAm	N	NA	NA
<i>Prunus domestica</i>	Rosaceae	Eur	N	NA	NA
<i>Pseudotsuga menziesii</i>	Pinaceae	NAm	N	NA	NA
<i>Ruta graveolens</i>	Rutaceae	Eur	N	NA	NA
<i>Salvia splendens</i>	Lamiaceae	SAm	Y	N	M
<i>Sedum sexangulare</i>	Crassulaceae	Eur	N	Y	H
<i>Sedum spurium</i>	Crassulaceae	Eur	N	NA	NA
<i>Solanum pseudocapsicum</i>	Solanaceae	SAm	N	NA	NA
<i>Spathodea campanulata</i>	Bignoniaceae	SAm	Y	N	L
<i>Syringa vulgaris</i>	Oleaceae	Eur	N	NA	NA
<i>Tagetes erecta</i>	Asteraceae	NAm	N	Y	M
<i>Tagetes patula</i>	Asteraceae	SAm	N	NA	NA
<i>Thunbergia alata</i>	Acanthaceae	Afr	Y	N	L
<i>Tipuana tipu</i>	Fabaceae	SAm	N	NA	NA
<i>Ulmus pumila</i>	Ulmaceae	As, AT	Y	Y	L
<i>Washingtonia filifera</i>	Arecaceae	NAm	N	NA	NA
<i>Zinnia elegans</i>	Asteraceae	SAm	N	NA	NA
c) Naturalized species					
<i>Actinidia chinensis</i>	Actinidiaceae	As	N		
<i>Aeonium arboreum</i>	Crassulaceae	Afr	N		
<i>Aesculus hippocastanum</i>	Sapindaceae	Eur	N		
<i>Alnus cordata</i>	Betulaceae	Eur	N		
<i>Ammannia coccinea</i>	Lythraceae	NAm	N		
<i>Anethum graveolens</i>	Apiaceae	Afr	N		
<i>Anthurium scherzerianum</i>	Anthuraceae	As-Eur	N		
<i>Aptenia cordifolia</i>	Aizoaceae	Afr	N		
<i>Aquilegia vulgaris</i>	Ranunculaceae	As, Eur	N		
<i>Austrocylindropuntia cylindrica</i>	Cactaceae	SAm	N		
<i>Bougainvillea glabra</i>	Nyctaginaceae	SAm	N		
<i>Cedrus atlantica</i>	Pinaceae	Afr	N		
<i>Cerastium tomentosum</i>	Caryophyllaceae	Eur	N		
<i>Chamaecyparis lawsoniana</i>	Cupressaceae	NAm	N		

	Family	Native distribution	Invasive elsewhere	Climate suitability	Confidence
<i>Chamaedorea elegans</i>	Arecaceae	NAm	N		
<i>Crataegus azarolus</i>	Rosaceae	Afr, As, Eur	N		
<i>Cuminum cyminum</i>	Apiaceae	Eur	N		
<i>Cupressus sempervirens</i>	Cupressaceae	Eur	N		
<i>Erysimum odoratum</i>	Brassicaceae	Eur	N		
<i>Euphorbia milli</i>	Euphorbiaceae	Afr	N		
<i>Hydrangea macrophylla</i>	Hydrangeaceae	As	N		
<i>Hydrocotyle verticillata</i>	Araliaceae	NAm	N		
<i>Hypericum calycinum</i>	Hypericaceae	Eur	N		
<i>Impatiens walleriana</i>	Balsaminaceae	Afr	N		
<i>Laburnum anagyroides</i>	Fabaceae	Eur	N		
<i>Lonicera nitida</i>	Caprifoliaceae	AS	N		
<i>Mespilus germanica</i>	Rosaceae	As, Eur	N		
<i>Parthenocissus tricuspidata</i>	Vitaceae	As, AT	N		
<i>Pelargonium graveolens</i>	Geraniaceae	Afr	N		
<i>Pelargonium peltatum</i>	Geraniaceae	Afr	N		
<i>Petroselinum crispum</i>	Apiaceae	Eur	N		
<i>Phoenix dactylifera</i>	Arecaceae	As	N		
<i>Physocarpus opulifolius</i>	Rosaceae	NAm	N		
<i>Picea abies</i>	Pinaceae	Eur	N		
<i>Picea omorika</i>	Pinaceae	Eur	N		
<i>Prunus cerasifera</i>	Rosaceae	Eur	N		
<i>Prunus laurocerasus</i>	Rosaceae	As	N		
<i>Pyrostegia venusta</i>	Bignoniaceae	SAm	N		
<i>Quercus rubra</i>	Fagaceae	NAm	N		
<i>Salix viminalis</i>	Salicaceae	Eur	N		
<i>Sequoiadendron giganteum</i>	Cupressaceae	NAm	N		
<i>Styphnolobium japonicum</i>	Fabaceae	As	N		
<i>Tamarix parviflora</i>	Tamaricaceae	Afr	N		
<i>Vitis vinifera</i>	Vitaceae	Eur	N		
<i>Washingtonia robusta</i>	Arecaceae	NAm	N		
<i>Yucca gloriosa</i>	Agavaceae	NAm	N		

Appendix 4

Table A4. Data deficient list. The Data Deficient List includes species for which we did not have sufficient data for analysis. Native distribution: Afr: Africa; As: Asia (Temperate); AT: Asia (Tropical); Aus: Australia; Eur: Europe; NAm: North America; Pac: Pacific; SAm: South and Center America.

Species with deficient data	Family	Native distribution
<i>Abelia chinensis</i>	Caprifoliaceae	As
<i>Abelia floribunda</i>	Caprifoliaceae	Nam
<i>Abies concolor</i>	Pinaceae	NAm
<i>Abies koreana</i>	Pinaceae	As
<i>Abies nordmanniana</i>	Pinaceae	As, Eur
<i>Abies procera</i>	Pinaceae	NAm
<i>Acacia floribunda</i>	Fabaceae	Aus
<i>Acacia pendula</i>	Fabaceae	Aus
<i>Acca sellowiana</i>	Myrtaceae	SAm
<i>Acer palmatum</i>	Sapindaceae	As
<i>Acer rubrum</i>	Sapindaceae	NAm
<i>Acer saccharinum</i>	Sapindaceae	NAm
<i>Acorus gramineus</i>	Acoraceae	AT, AS
<i>Actinidia arguta</i>	Actinidiaceae	As
<i>Actinidia deliciosa</i>	Actinidiaceae	As
<i>Adenium obesum</i>	Apocynaceae	Afr
<i>Aechmea fasciata</i>	Bromeliaceae	SAm
<i>Agapanthus africanus</i>	Amaryllidaceae	Afr
<i>Agave attenuata</i>	Agavaceae	SAm
<i>Agave bracteosa</i>	Agavaceae	NAm
<i>Agave filifera</i>	Agavaceae	SAm
<i>Agave guiengola</i>	Agavaceae	SAm
<i>Agave horrida</i>	Agavaceae	SAm
<i>Agave lechuguilla</i>	Agavaceae	SAm
<i>Agave macroacantha</i>	Agavaceae	SAm
<i>Agave salmiana</i>	Agavaceae	SAm
<i>Agave victoriae-reginae</i>	Agavaceae	SAm
<i>Agave xylonacantha</i>	Agavaceae	SAm
<i>Allagoptera arenaria</i>	Arecaceae	SAm
<i>Allium schoenoprasum</i>	Amaryllidaceae	NAm
<i>Alocasia wentii</i>	Araceae	Aus
<i>Aloe marlothii</i>	Liliaceae	Afr
<i>Aloe variegata</i>	Xanthorrhoeaceae	Afr
<i>Alpinia caerulea</i>	Zigimberaceae	Aus
<i>Alternanthera peruensis</i>	Amaranthaceae	SAm
<i>Alternanthera reinekii</i>	Amaranthaceae	SAm
<i>Alternanthera rosaeivolia</i>	Amaranthaceae	SAm
<i>Anacardium occidentale</i>	Anacardiaceae	SAm
<i>Andromeda polifolia</i>	Ericaceae	Eur, As, NAm
<i>Anemantele lessoniana</i>	Poaceae	Aus
<i>Anemone blanda</i>	Ranunculaceae	Eur
<i>Anisodonteia capensis</i>	Malvaceae	Afr

Species with deficient data	Family	Native distribution
<i>Aphelandra squarrosa</i>	Acanthaceae	SAm
<i>Arabis alpina</i>	Brassicaceae	AT
<i>Araucaria araucana</i>	Araucariaceae	SAm
<i>Araucaria heterophylla</i>	Araucariaceae	Aus
<i>Archontophoenix alexandrae</i>	Arecaceae	Aus
<i>Archontophoenix purpurea</i>	Arecaceae	Aus
<i>Arctotis fastuosa</i>	Asteraceae	Afr
<i>Arenga engleri</i>	Arecaceae	AT
<i>Argyranthemum frutescens</i>	Asteraceae	Afr
<i>Arrojadoa rhodantha</i>	Cactaceae	SAm
<i>Asparagus setaceus</i>	Asparagaceae	Afr
<i>Aspidistra elatior</i>	Asparagaceae	AT
<i>Athyrium nipponicum</i>	Athyriaceae	As
<i>Aucuba japonica</i>	Garryaceae	As
<i>Balantium antarcticum</i>	Dicksoniaceae	Aus
<i>Banksia integrifolia</i>	Proteaceae	Aus
<i>Bauhinia purpurea</i>	Fabaceae	SAm
<i>Beaucarnea recurvata</i>	Asparagaceae	SAm
<i>Begonia cucullata</i>	Begoniaceae	AT
<i>Begonia rex</i>	Begoniaceae	AT
<i>Berberis julianae</i>	Berberidaceae	As
<i>Berberis microphylla</i>	Berberidaceae	SAm
<i>Bergenia cordifolia</i>	Saxifragaceae	As
<i>Beschorneria yuccoides</i>	Agavaceae	NAm
<i>Betula papyrifera</i>	Betulaceae	NAm
<i>Betula utilis</i>	Betulaceae	As
<i>Boronia crenulata</i>	Rutaceae	Aus
<i>Boswellia carterii</i>	Burseraceae	Afr
<i>Brachychiton acerifolius</i>	Malvaceae	Aus
<i>Brachychiton bidwillii</i>	Malvaceae	Aus
<i>Brachychiton discolor</i>	Malvaceae	Aus
<i>Brachychiton rupestris</i>	Malvaceae	Aus
<i>Brachyscome multifida</i>	Asteraceae	Aus
<i>Brasiliopuntia brasiliensis</i>	Cactaceae	SAm
<i>Bulbine frutescens</i>	Liliaceae	Afr
<i>Butia eriospatha</i>	Arecaceae	SAm
<i>Butia yatai</i>	Arecaceae	SAm
<i>Buxus microphylla</i>	Buxaceae	As
<i>Callistemon viminalis</i>	Myrtaceae	Aus
<i>Callistephus chinensis</i>	Asteraceae	As
<i>Callitropsis nootkatensis</i>	Cupressaceae	NAm
<i>Calothamnus quadrifidus</i>	Myrtaceae	Aus
<i>Camellia japonica</i>	Theaceae	As
<i>Camellia sasanqua</i>	Theaceae	As
<i>Campanula carpatica</i>	Campanulaceae	Eur
<i>Campanula isophylla</i>	Campanulaceae	Eur
<i>Carex comans</i>	Cyperaceae	Aus
<i>Carica papaya</i>	Caricaceae	SAm

Species with deficient data	Family	Native distribution
<i>Carissa macrocarpa</i>	Apocynaceae	Afr
<i>Carya illinoensis</i>	Juglandaceae	NAm
<i>Caryota maxima</i>	Arecaceae	Eur
<i>Caryota mitis</i>	Arecaceae	AT
<i>Caryota urens</i>	Arecaceae	AT
<i>Casimiroa edulis</i>	Rutaceae	SAm
<i>Catalpa bungei</i>	Bignoniaceae	As
<i>Ceanothus integerrimus</i>	Rhamnaceae	NAm
<i>Ceiba speciosa</i>	Malvaceae	SAm
<i>Celtis occidentalis</i>	Cannabaceae	NAm
<i>Cephalocereus senilis</i>	Cactaceae	NAm
<i>Cercidiphyllum japonicum</i>	Cercidiphyllaceae	As
<i>Cereus jamacaru</i>	Cactaceae	SAm
<i>Ceropegia woodii</i>	Apocynaceae	Afr
<i>Chaenomeles japonica</i>	Rosaceae	As
<i>Chamaecyparis obtusa</i>	Cupressaceae	As
<i>Chamaecyparis pisifera</i>	Cupressaceae	As
<i>Chamaecyparis thyoides</i>	Cupressaceae	NAm
<i>Chambeyronia macrocarpa</i>	Arecaceae	Aus
<i>Chamelaucium uncinatum</i>	Myrtaceae	Aus
<i>Chlorophytum comosum</i>	Agavaceae	Afr
<i>Choisya ternata</i>	Rutaceae	NAm
<i>Citronella mucronata</i>	Cardiopteridaceae	SAm
<i>Citrus limetta</i>	Rutaceae	As
<i>Citrus medica</i>	Rutaceae	AT
<i>Citrus reticulata</i>	Rutaceae	As
<i>Cleistocactus strausii</i>	Cactaceae	SAm
<i>Cleyera japonica</i>	Pentaphylacaceae	As
<i>Cocos nucifera</i>	Arecaceae	Afr, AT, SAm, Pac
<i>Codiaeum variegatum</i>	Euphorbiaceae	AT
<i>Convolvulus cneorum</i>	Convolvulacea	Eur, Afr
<i>Copernicia alba</i>	Arecaceae	SAm
<i>Cordyline fruticosa</i>	Asparagaceae	AT
<i>Cordyline indivisa</i>	Asparagaceae	Aus
<i>Coreopsis grandiflora</i>	Asteraceae	NAm
<i>Cornus controversa</i>	Cornaceae	As
<i>Cornus forida</i>	Cornaceae	NAm
<i>Cornus kousa</i>	Cornaceae	As
<i>Corylus colurna</i>	Betulaceae	As, Eur
<i>Corylus maxima</i>	Betulaceae	Eur
<i>Cotoneaster coriaceous</i>	Rosaceae	AT
<i>Cotoneaster dammeri</i>	Rosaceae	As
<i>Cotoneaster salicifolius</i>	Rosaceae	As
<i>Crassula sarcocaulis</i>	Crassulaceae	Afr
<i>Crotalaria capensis</i>	Fabaceae	Afr
<i>Cryptocoryne albida</i>	Araceae	AT
<i>Cryptocoryne parva</i>	Araceae	AT
<i>Cryptocoryne pygmaea</i>	Araceae	AT

Species with deficient data	Family	Native distribution
<i>Cryptocoryne tonkinensis</i>	Araceae	AT
<i>Cryptocoryne walkeri</i>	Araceae	AT
<i>Cryptocoryne wendtii</i>	Araceae	AT
<i>Cryptomeria japonica</i>	Cupressaceae	As
<i>Cuphea hyssopifolia</i>	Lythraceae	NAm
<i>Cussonia spicata</i>	Araliaceae	Afr
<i>Cycas circinalis</i>	Cycadaceae	AT
<i>Cyclamen persicum</i>	Primulaceae	Eur
<i>Cyperus papyrus</i>	Cyperaceae	Afr
<i>Dasylirion lucidum</i>	Asparagaceae	NAm
<i>Dasylirion serratifolium</i>	Asparagaceae	NAm
<i>Delosperma congestum</i>	Aizoaceae	Afr
<i>Dianthus chinensis</i>	Caryophyllaceae	As
<i>Dieffenbachia seguine</i>	Araceae	SAm
<i>Dionaea muscipula</i>	Droseraceae	NAm
<i>Dioon edule</i>	Zamiaceae	NAm
<i>Dombeya tiliacea</i>	Malvaceae	Afr
<i>Dracaena braunii</i>	Asparagaceae	Afr
<i>Dracaena draco</i>	Asparagaceae	Afr
<i>Dracaena fragans</i>	Asparagaceae	Afr
<i>Dracaena reflexa</i>	Asparagaceae	Afr
<i>Drosanthemum speciosum</i>	Aizoaceae	Afr
<i>Dyopsis decaryi</i>	Arecaceae	Afr
<i>Dyopsis decipiens</i>	Arecaceae	Afr
<i>Dyopsis lutescens</i>	Arecaceae	Afr
<i>Ecchinodorus tenellus</i>	Alismataceae	NAm
<i>Echinocactus grusonii</i>	Cactaceae	NAm
<i>Echinocereus nivosus</i>	Cactaceae	NAm
<i>Echinodorus ozelot</i>	Alismataceae	NAm
<i>Echinodorus paniculatus</i>	Alismataceae	NAm
<i>Echinodorus parviflora</i>	Alismataceae	NAm
<i>Echinodorus tenellus</i>	Alismataceae	NAm
<i>Echinopsis eyriesii</i>	Cactaceae	SAm
<i>Echinopsis huascha</i>	Cactaceae	SAm
<i>Echinopsis macrogona</i>	Cactaceae	SAm
<i>Egeria najas</i>	Hydrocharitaceae	SAm
<i>Ensete ventricosum</i>	Musaceae	Afr
<i>Epipremnum aureum</i>	Araceae	AT
<i>Erythrina caffra</i>	Fabaceae	Afr
<i>Erythrina crista-galli</i>	Fabaceae	SAm
<i>Erythrina falcata</i>	Fabaceae	SAm
<i>Escallonia macrantha</i>	Escalloniaceae	SAm
<i>Esposita guentheri</i>	Cactaceae	SAm
<i>Esposita lanata</i>	Cactaceae	SAm
<i>Eucalyptus coccifera</i>	Myrtaceae	Aus
<i>Eucalyptus nitens</i>	Myrtaceae	Aus
<i>Eucalyptus parvifolia</i>	Myrtaceae	Aus
<i>Eugenia brasiliensis</i>	Myrtaceae	SAm

Species with deficient data	Family	Native distribution
<i>Euphorbia abyssinica</i>	Euphorbiaceae	Afr
<i>Euphorbia avasmontana</i>	Euphorbiaceae	SAm
<i>Euphorbia baioensis</i>	Euphorbiaceae	Afr
<i>Euphorbia ingens</i>	Euphorbiaceae	Afr
<i>Euphorbia martinae</i>	Euphorbiaceae	Afr
<i>Euphorbia pseudocactus</i>	Euphorbiaceae	Afr
<i>Euphorbia pulcherrima</i>	Euphorbiaceae	SAm
<i>Euphorbia trigona</i>	Euphorbiaceae	Afr
<i>Euryops chrysanthemoides</i>	Asteraceae	Afr
<i>Euryops pectinatus</i>	Asteraceae	Afr
<i>Exacum affine</i>	Gentianaceae	Afr
<i>Fatsia japonica</i>	Araliaceae	As
<i>Felicia amelloides</i>	Asteraceae	Afr
<i>Ferocactus emoryi</i>	Cactaceae	NAm
<i>Ferocactus glaucescens</i>	Cactaceae	NAm
<i>Ferocactus gracilis</i>	Cactaceae	NAm
<i>Ferocactus pilosus</i>	Cactaceae	NAm
<i>Ficus macrophylla</i>	Moraceae	Aus
<i>Firmiana simplex</i>	Malvaceae	As, AT
<i>Fissidens fontanus</i>	Flissidentaceae	NAm
<i>Fontinalis antipyretica</i>	Fontanilaceae	NAm
<i>Fortunella japonica</i>	Rutaceae	As
<i>Gazania splendens</i>	Asteraceae	Afr
<i>Gelsemium sempervirens</i>	Gelsemiaceae	NAm
<i>Genista lydia</i>	Fabaceae	Eur
<i>Ginkgo biloba</i>	Ginkgoaceae	As
<i>Grevillea juniperina</i>	Proteaceae	Aus
<i>Grevillea lanigera</i>	Proteaceae	Aus
<i>Griselinia littoralis</i>	Griselinaceae	Aus
<i>Hamamelis virginiana</i>	Hammamelidaceae	NAm
<i>Handroanthus chrysanthus</i>	Bignoniaceae	SAm
<i>Hardenbergia comptoniana</i>	Fabaceae	Aus
<i>Haworthia fasciata</i>	Xanthorrhoeaceae	Afr
<i>Hebe diosmifolia</i>	Plantaginaceae	Aus
<i>Hebe odora</i>	Plantaginaceae	Aus
<i>Hebe topiaria</i>	Plantaginaceae	Aus
<i>Hedera algeriensis</i>	Araliaceae	Afr
<i>Hedera canariensis</i>	Araliaceae	Afr
<i>Hottonia inflata</i>	Primulaceae	NAm
<i>Howea forsteriana</i>	Arecaceae	Pac
<i>Hoya carnosae</i>	Asclepiadaceae	AT, Aus
<i>Hydrangea paniculata</i>	Hydrangeaceae	As
<i>Hydrocotyle tripartita</i>	Araliaceae	Aus
<i>Impatiens hawkeri</i>	Balsaminaceae	Aus
<i>Jasminum grandiflorum</i>	Oleaceae	Afr, AT
<i>Jasminum meznii</i>	Oleaceae	As
<i>Jubaea chilensis</i>	Arecaceae	SAm
<i>Juniperus chinensis</i>	Cupressaceae	As

Species with deficient data	Family	Native distribution
<i>Juniperus horizontalis</i>	Cupressaceae	NAm
<i>Juniperus scopulorum</i>	Cupressaceae	NAm
<i>Juniperus squamata</i>	Cupressaceae	As
<i>Justicia brandegeana</i>	Acanthaceae	SAm
<i>Kalanchoe beharensis</i>	Crassulaceae	Afr
<i>Kalanchoe blossfeldiana</i>	Crassulaceae	Afr
<i>Kerria japonica</i>	Rosaceae	As
<i>Koelreuteria bipinnata</i>	Sapindaceae	As
<i>Lampranthus spectabilis</i>	Aizoaceae	Afr
<i>Leucanthemum paludosum</i>	Asteraceae	Eur
<i>Leucothoe fontanesiana</i>	Ericaceae	NAm
<i>Licuala grandis</i>	Arecaceae	Aus
<i>Ligustrum japonicum</i>	Oleaceae	As
<i>Liquidambar styraciflua</i>	Hamamelidaceae	NAm
<i>Liriodendron tulipifera</i>	Magnoliaceae	NAm
<i>Litchi chinensis</i>	Sapindaceae	AT
<i>Livistona australis</i>	Arecaceae	Aus
<i>Lobelia cardinalis</i>	Campanulaceae	NAm
<i>Lomariopsis lineata</i>	Lomaropsidaceae	AT, Aus
<i>Lophophora williamsii</i>	Cactaceae	NAm
<i>Macrozamia communis</i>	Cicadaceae	Aus
<i>Magnolia denudata</i>	Magnoliaceae	As
<i>Magnolia grandiflora</i>	Magnoliaceae	NAm
<i>Magnolia stellata</i>	Magnoliaceae	As
<i>Malpighia emarginata</i>	Malpighiaceae	SAm
<i>Malus floribunda</i>	Rosaceae	As
<i>Mammillaria geminispina</i>	Cactaceae	NAm
<i>Mammillaria magnifica</i>	Cactaceae	NAm
<i>Mammillaria rhodantha</i>	Cactaceae	NAm
<i>Melaleuca ericifolia</i>	Myrtaceae	Aus
<i>Melaleuca linearis</i>	Myrtaceae	Aus
<i>Melocactus neryi</i>	Cactaceae	SAm
<i>Melocactus zehntneri</i>	Cactaceae	SAm
<i>Mentha crispata</i>	Lamiaceae	Cosm
<i>Metasequoia glyptostroboides</i>	Taxodiaceae	As
<i>Metrosideros excelsa</i>	Myrtaceae	Aus
<i>Micranthemum callitrichoides</i>	Scrophulariaceae	SAm
<i>Micranthemum micranthemoides</i>	Scrophulariaceae	NAm
<i>Micromeria fruticosa</i>	Lamiaceae	Eur
<i>Microsorium pteropus</i>	Polypodiaceae	AT
<i>Morus australis</i>	Moraceae	AT
<i>Musa acuminata</i>	Musaceae	AT, Aus
<i>Musa basjoo</i>	Musaceae	As
<i>Myriophyllum mattogrossense</i>	Haloragidaceae	SAm
<i>Myrtillocactus geometrizans</i>	Cactaceae	NAm
<i>Nannorrhops ritchieana</i>	Arecaceae	As
<i>Nasella tenuissima</i>	Poaceae	SAm
<i>Nemesia strumosa</i>	Scrophulariaceae	Afr

Species with deficient data	Family	Native distribution
<i>Nertera granadensis</i>	Rubiaceae	SAm, Pac
<i>Nolina longifolia</i>	Asparagaceae	NAm
<i>Nyssa sylvatica</i>	Cornaceae	NAm
<i>Opuntia macrocentra</i>	Cactaceae	NAm
<i>Opuntia pubescens</i>	Cactaceae	SAm
<i>Oreocereus celsianus</i>	Cactaceae	SAm
<i>Oreocereus doelzianus</i>	Cactaceae	SAm
<i>Oreocereus leucotrichus</i>	Cactaceae	SAm
<i>Osmanthus heterophyllus</i>	Oleaceae	As
<i>Ostrya carpinifolia</i>	Betulaceae	Eur
<i>Pachira aquatica</i>	Bombacaceae	SAm
<i>Pachycereus marginatus</i>	Cactaceae	NAm
<i>Pachycereus pecten-aboriginum</i>	Cactaceae	NAm
<i>Pachycereus pringlei</i>	Cactaceae	NAm
<i>Pachypodium lamerei</i>	Apocynaceae	Afr
<i>Pachysandra terminalis</i>	Buxaceae	As
<i>Pandanus utilis</i>	Pandanaceae	Afr
<i>Pandorea jasminoides</i>	Bignoniaceae	Aus
<i>Panicum virgatum</i>	Poaceae	NAm
<i>Parajubaea cocoides</i>	Arecaceae	SAm
<i>Parajubaea torralyi</i>	Arecaceae	SAm
<i>Parrotia persica</i>	Hamamelidaceae	Eur
<i>Passiflora incarnata</i>	Passifloraceae	SAm
<i>Passiflora manicata</i>	Passifloraceae	SAm
<i>Pelargonium grandiflorum</i>	Geraniaceae	Afr
<i>Pellia epiphylla</i>	Pelliaceae	As, Eur, NAm, Afr
<i>Pennisetum alopecuroides</i>	Poaceae	As, AT, Aus
<i>Pennisetum messiacum</i>	Poaceae	Afr
<i>Pennisetum orientale</i>	Poaceae	Afr, AT
<i>Pentas lanceolata</i>	Rubiaceae	Afr
<i>Pereskiaopsis rotundifolia</i>	Cactaceae	NAm
<i>Persea americana</i>	Lauraceae	SAm
<i>Phanera variegata</i>	Fabaceae	AT
<i>Philodendron bipinnatifidum</i>	Araceae	SAm
<i>Philodendron tuxtla</i>	Araceae	SAm
<i>Phlox subulata</i>	Polemoniaceae	NAm
<i>Phoenix reclinata</i>	Arecaceae	Afr
<i>Phoenix roebelenii</i>	Arecaceae	As, AT
<i>Phoenix theophrasti</i>	Arecaceae	Eur
<i>Phyllostrachys aurea</i>	Poaceae	As
<i>Picea glauca</i>	Pinaceae	NAm
<i>Picea koraiensis</i>	Pinaceae	As
<i>Picea pungens</i>	Pinaceae	NAm
<i>Pieris japonica</i>	Ericaceae	As, AT
<i>Pilosocereus leucocephalus</i>	Cactaceae	NAm
<i>Pilosocereus pachycladus</i>	Cactaceae	SAm
<i>Pinus brutia</i>	Pinaceae	Eur
<i>Pinus mugo</i>	Pinaceae	SAm

Species with deficient data	Family	Native distribution
<i>Pinus palustris</i>	Pinaceae	NAm
<i>Pistacia atlantica</i>	Anacardiaceae	Afr
<i>Pistacia chinensis</i>	Anacardiaceae	As
<i>Platanus orientalis</i>	Platanaceae	Eur
<i>Plectranthus verticillatus</i>	Lamiaceae	Afr
<i>Plumeria alba</i>	Apocynaceae	SAm
<i>Plumeria rubra</i>	Apocynaceae	SAm
<i>Polaskia chichipe</i>	Cactaceae	NAm
<i>Polaskia chula</i>	Cactaceae	NAm
<i>Polianthes tuberosa</i>	Amaryllidaceae	SAm
<i>Polygala myrtifolia</i>	Polygalaceae	Afr
<i>Portulaca umbraticola</i>	Portulacaceae	NAm
<i>Primula obconica</i>	Primulaceae	As
<i>Pritchardia hillebrandii</i>	Arecaceae	Pac
<i>Prunus serrulata</i>	Rosaceae	As
<i>Prunus subhirtella</i>	Rosaceae	As
<i>Pseudophoenix sargentii</i>	Arecaceae	NAm
<i>Pterocarya fraxinifolia</i>	Juglandaceae	Eur
<i>Puya chilensis</i>	Bromeliaceae	SAm
<i>Pyrus pyrifolia</i>	Rosaceae	As
<i>Quercus palustris</i>	Fagaceae	NAm
<i>Radermachera sinica</i>	Bignoniaceae	AT
<i>Ranunculus asiaticus</i>	Ranunculaceae	Eur, Afr
<i>Ravenala madagascariensis</i>	Strelitziaceae	Afr
<i>Ravenea rivularis</i>	Arecaceae	Afr
<i>Rhapidophyllum hystrix</i>	Arecaceae	NAm
<i>Rhapis excelsa</i>	Arecaceae	As
<i>Rhododendron arboreum</i>	Ericaceae	AT
<i>Rhododendron molle</i>	Ericaceae	As
<i>Ribes nigrum</i>	Grossulariaceae	Eur
<i>Ribes sanguineum</i>	Grossulariaceae	NAm
<i>Rotala rotundifolia</i>	Lythraceae	AT
<i>Roystonea regia</i>	Arecaceae	NAm
<i>Rubus spectabilis</i>	Rosaceae	NAm
<i>Russelia equisetiformis</i>	Scrophulariaceae	NAm
<i>Sabal mexicana</i>	Arecaceae	NAm
<i>Sabal minor</i>	Arecaceae	NAm
<i>Sabal palmetto</i>	Arecaceae	NAm
<i>Salix integra</i>	Salicaceae	As
<i>Salix matsudana</i>	Salicaceae	As
<i>Sansevieria perrottii</i>	Asparagaceae	Afr
<i>Schefflera arboricola</i>	Araliaceae	AT
<i>Scindapsus pictus</i>	Araceae	AT
<i>Sedum spectabile</i>	Crassulaceae	As
<i>Selaginella lepidophylla</i>	Selaginellaceae	NAm
<i>Sequoia sempervirens</i>	Cupressaceae	NAm
<i>Skimmia japonica</i>	Rutaceae	As
<i>Sorbus intermedia</i>	Rosaceae	Eur

Species with deficient data	Family	Native distribution
<i>Sorbus torminalis</i>	Rosaceae	Eur, Afr
<i>Staurogyne repens</i>	Acanthaceae	SAm
<i>Stenocarpus sinuatus</i>	Proteaceae	Aus
<i>Stephanotis floribunda</i>	Apocynaceae	Afr
<i>Stetsonia coryne</i>	Cactaceae	SAm
<i>Stevia rebaudiana</i>	Asteraceae	SAm
<i>Strelitzia nicolai</i>	Stelitzaceae	Afr
<i>Strelitzia reginae</i>	Stelitzaceae	Afr
<i>Syagrus romanzoffiana</i>	Arecaceae	SAm
<i>Syagrus yungasensis</i>	Arecaceae	SAm
<i>Symphoricarpos orbiculatus</i>	Caprifoliaceae	NAm
<i>Taxiphyllum alternans</i>	Hypnaceae	AT
<i>Taxiphyllum barbieri</i>	Hypnaceae	AT
<i>Taxodium distichum</i>	Taxodiaceae	NAm
<i>Tetraclinis articulata</i>	Cupressaceae	Afr
<i>Thuja occidentalis</i>	Cupressaceae	NAm
<i>Thuja plicata</i>	Cupressaceae	NAm
<i>Thymus citriodorus</i>	Lamiaceae	Cosm
<i>Tilia americana</i>	Malvaceae	NAm
<i>Tilia tormentosa</i>	Malvaceae	Eur
<i>Tillandsia flabellata</i>	Bromeliaceae	SAm
<i>Trachelospermum jasminoides</i>	Apocynaceae	As, AT
<i>Trachycarpus martianus</i>	Arecaceae	As
<i>Trithrinax campestris</i>	Arecaceae	SAm
<i>Ugni molinae</i>	Myrtaceae	SAm
<i>Utricularia graminifolia</i>	Lentibulariaceae	AT
<i>Vaccinium macrocarpon</i>	Ericaceae	NAm
<i>Vallisneria americana</i>	Hydrocharitaceae	NAm
<i>Vallisneria spiralis</i>	Hydrocharitaceae	Aus
<i>Veitchia joannis</i>	Arecaceae	Aus
<i>Vesicularia dubyana</i>	Hypnaceae	AT
<i>Vesicularia montagnei</i>	Hypnaceae	AT
<i>Viburnum davidii</i>	Adoxaceae	As
<i>Viburnum plicatum</i>	Adoxaceae	As
<i>Viburnum sargentii</i>	Adoxaceae	As
<i>Vriesea splendens</i>	Bromeliaceae	SAm
<i>Weigela florida</i>	Diervillaceae	As
<i>Wodyetia bifurcata</i>	Arecaceae	Aus
<i>Xerochrysum bracteatum</i>	Asteraceae	Aus
<i>Yucca elephantipes</i>	Agavaceae	SAm
<i>Yucca filamentosa</i>	Agavaceae	NAm
<i>Yucca filifera</i>	Agavaceae	NAm
<i>Yucca glauca</i>	Agavaceae	NAm
<i>Yucca rostrata</i>	Agavaceae	NAm
<i>Zamia furfuracea</i>	Zamiaceae	NAm
<i>Zamioculcas zamiifolia</i>	Araceae	Afr
<i>Zelkova carpinifolia</i>	Ulmaceae	Eur